Preliminary report for IRI changes after KUMAMOTO earthquake Japan, by using Smartphone roughness measurement

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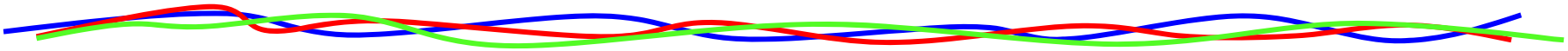
Smartphone response type Roughness measurement



Precise Measurement Vehicles

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Roughness measurement

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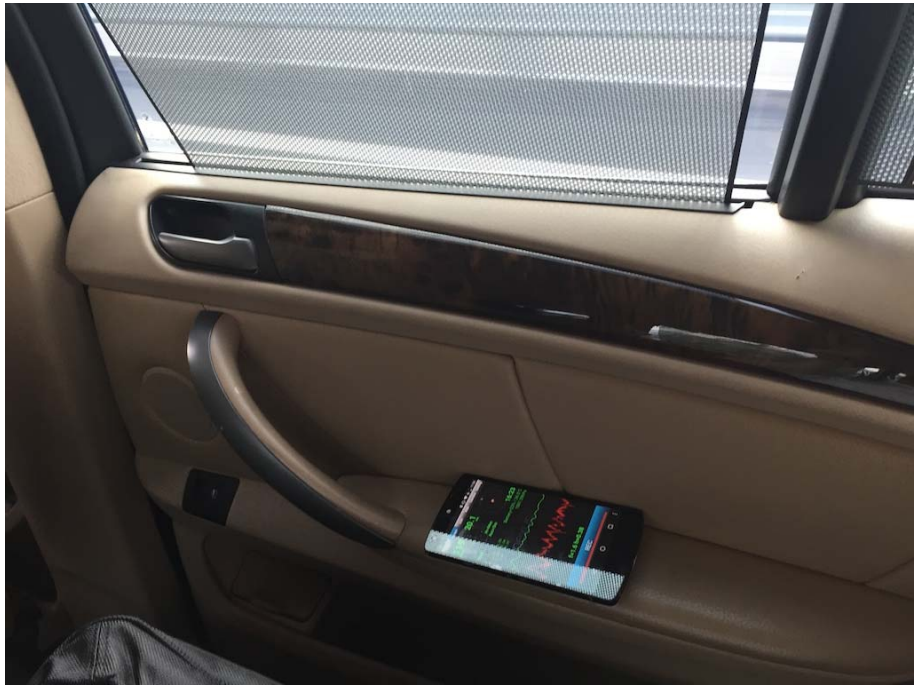
I ride a taxi.

I have a smartphone.

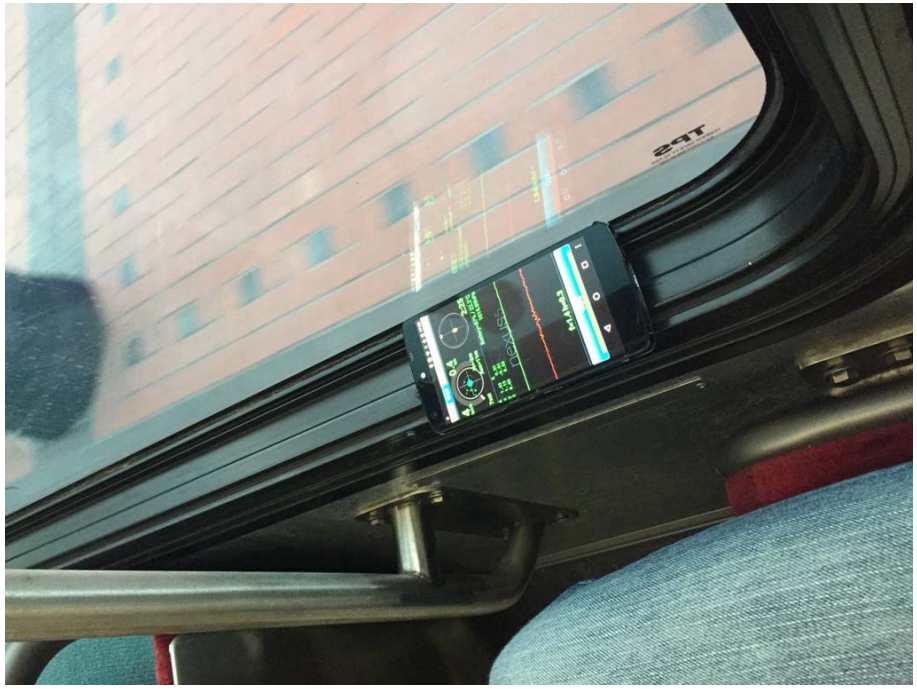


Roughness measurement

BumpRecorder

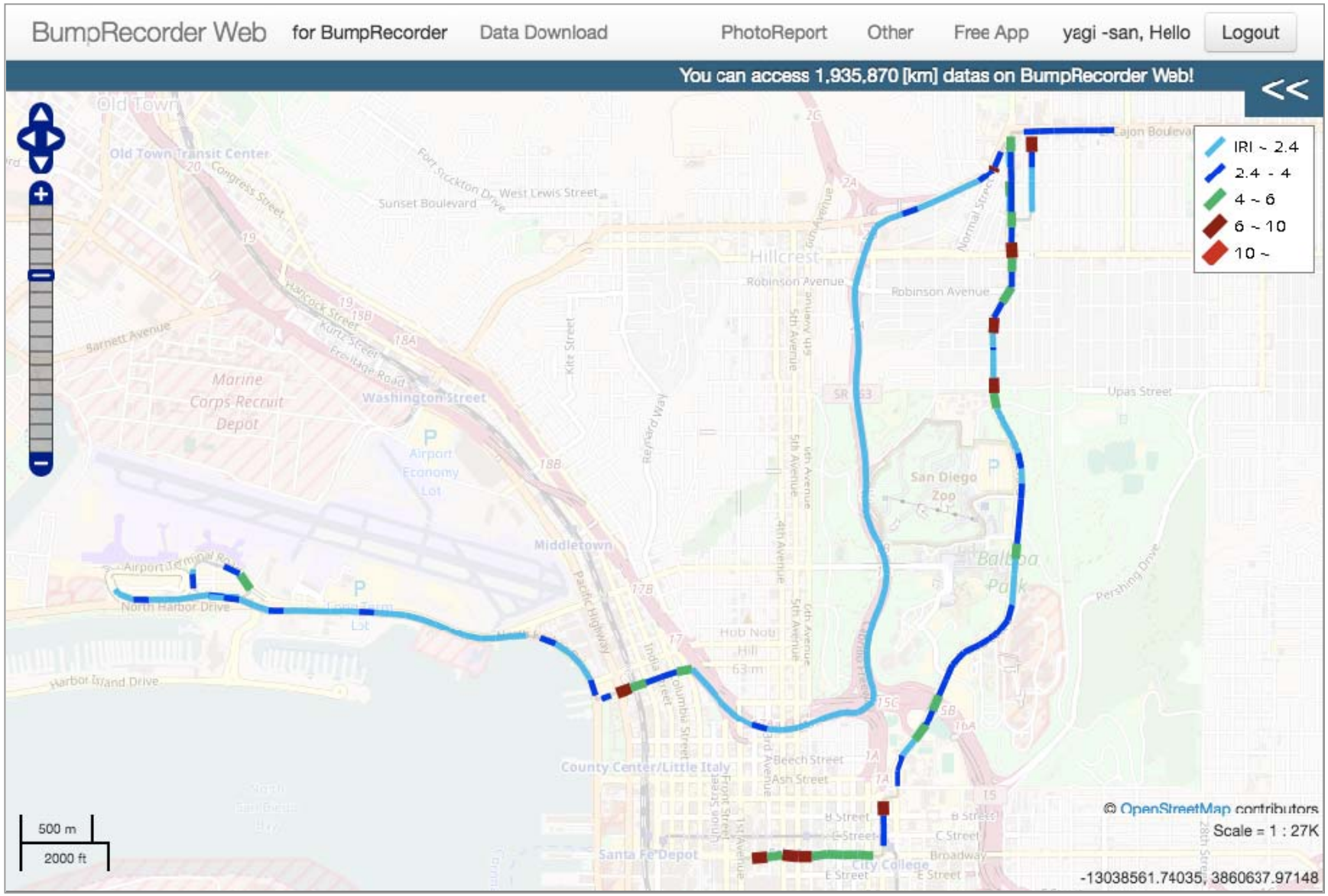
I ride a bus.

I have a smartphone.



IRI situations at San Diego

BumpRecorder



From airport to hotel

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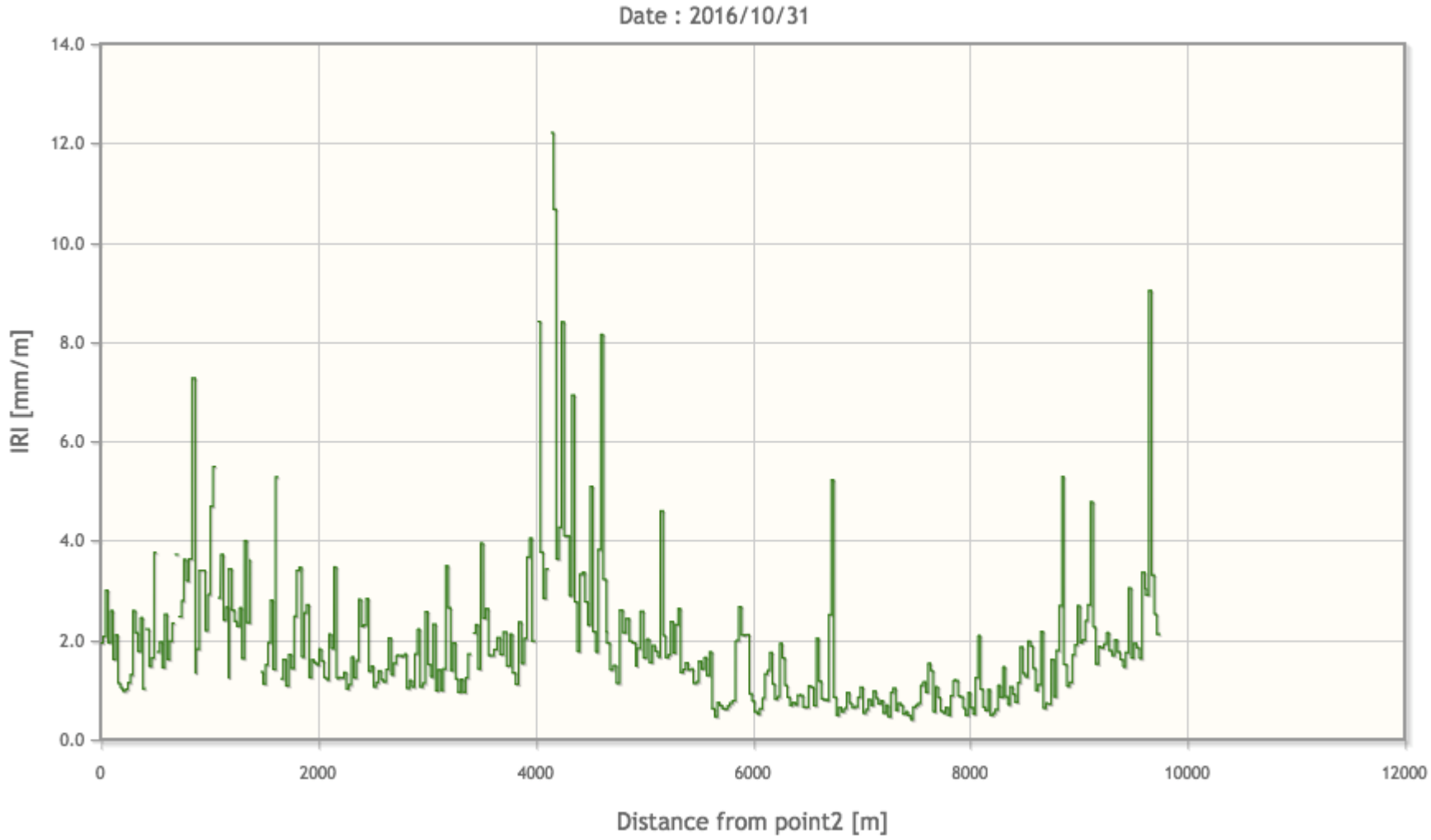
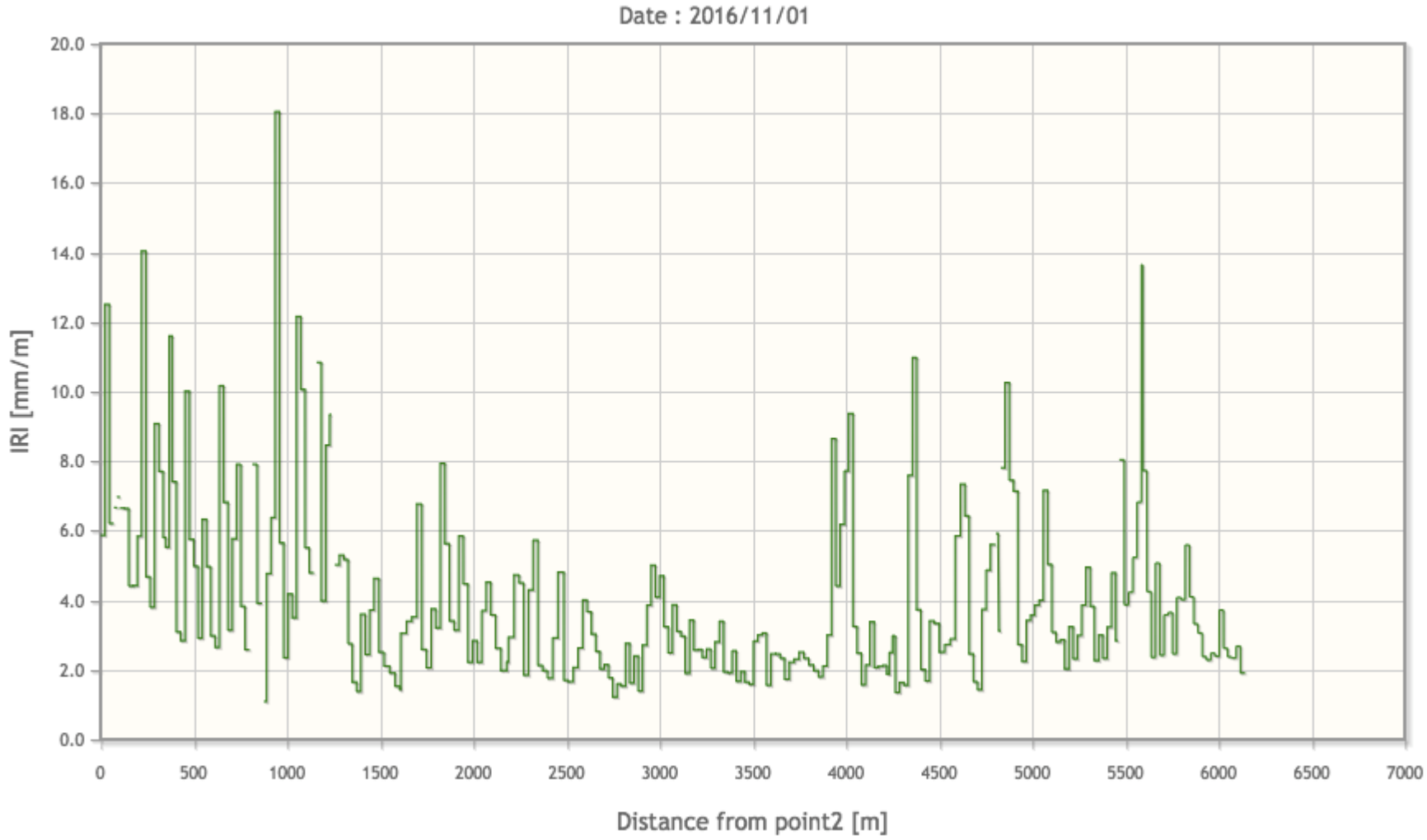


From downtown to hotel

BumpRecorder



What is right monitoring?

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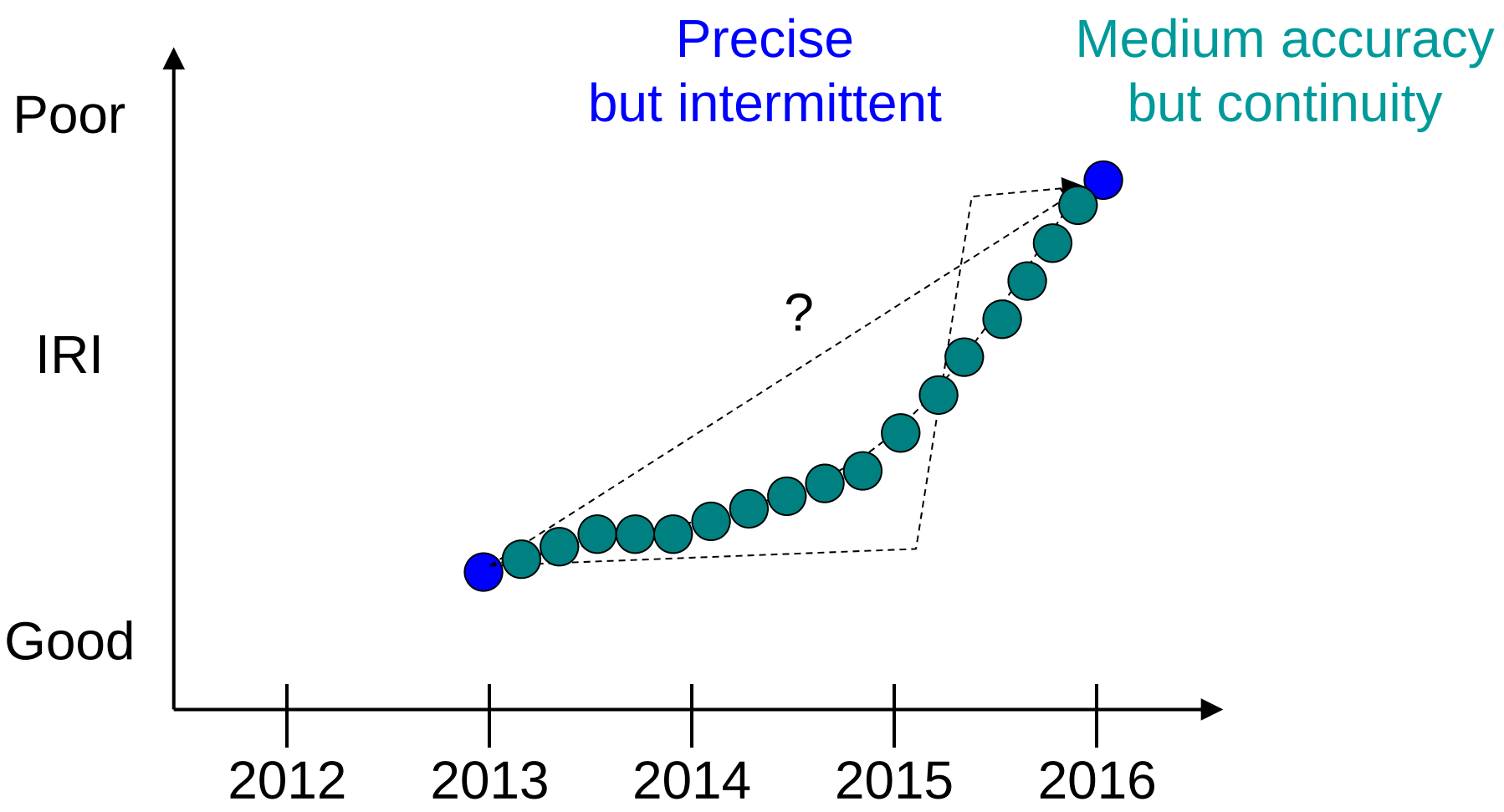

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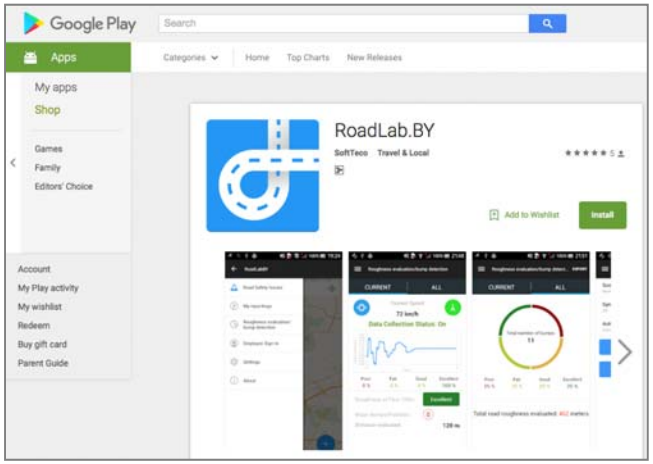
Global trend
Smartphone measurement

The World Bank start to provide "RoadLab".

Global road roughness standard "IRI" - International Roughness Index - is defined by the World Bank.

At 95th TRB - Transportation Research Board - Annual Meeting 2016, they announced to start provide Smartphone App "RoadLab" for measurement road roughness by Smartphone.



What is right monitoring?

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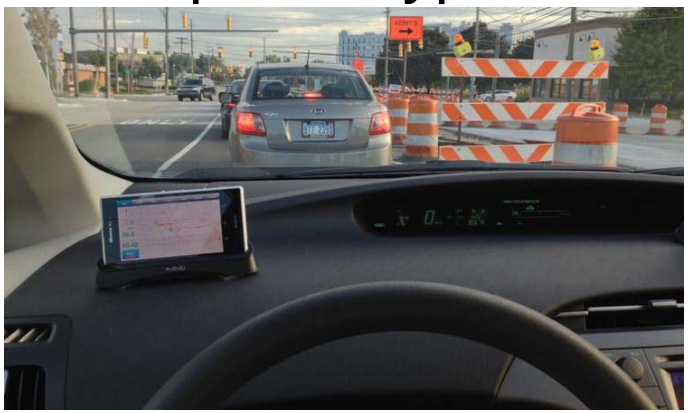
Pavement health monitoring

Smartphone type



Inertial profiler

Human health monitoring

Blood pressure

CT scanner

Our Main Costumers

BumpRecorder

- National agency
  MLIT (Ministry of Land, Infrastructure, Transport and Tourism)

- Local government
  Aizu-wakamatsu city,
  will be Tokyo Kita ward, Katsushika ward,
  Shizuoka pref & city

- Public authorities
  JICE (Japan Institute of Country-ology and Engineering)
  NILIM (National Institute for Land and Infrastructure Management)
  NIED (National Research Institute for Earth Science and Disaster Resilience)

Our Main Costumers

BumpRecorder

- Academia
  Tokyo University
  Kyoto University

- Private sectors
  13 companies e.g. TOA Road Corporation.

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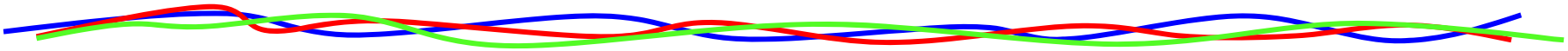
Earthquake Situations



Past Earthquake in Japan

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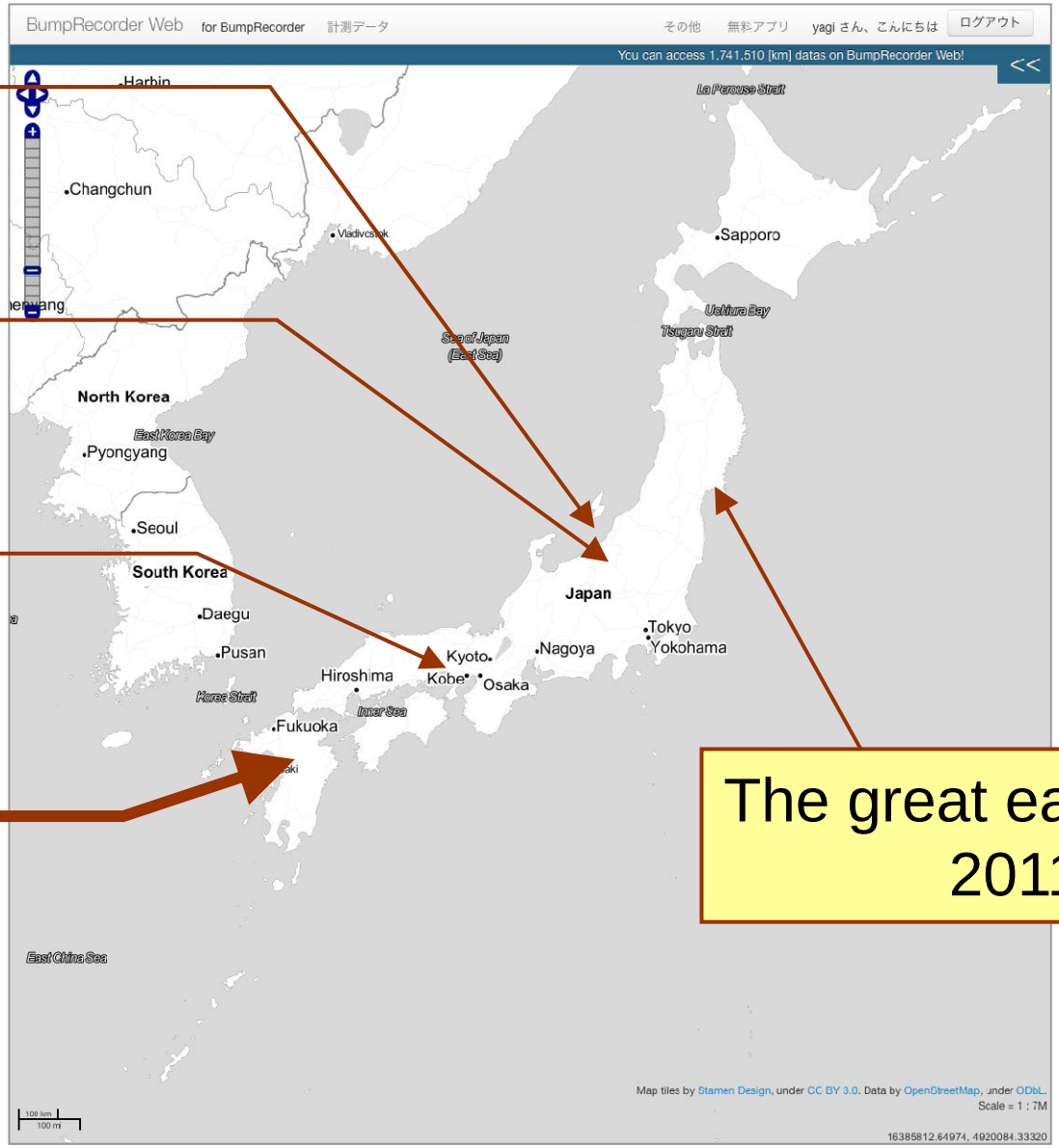
Chuetu oki 2007

Chuetu 2004

Kobe 1995

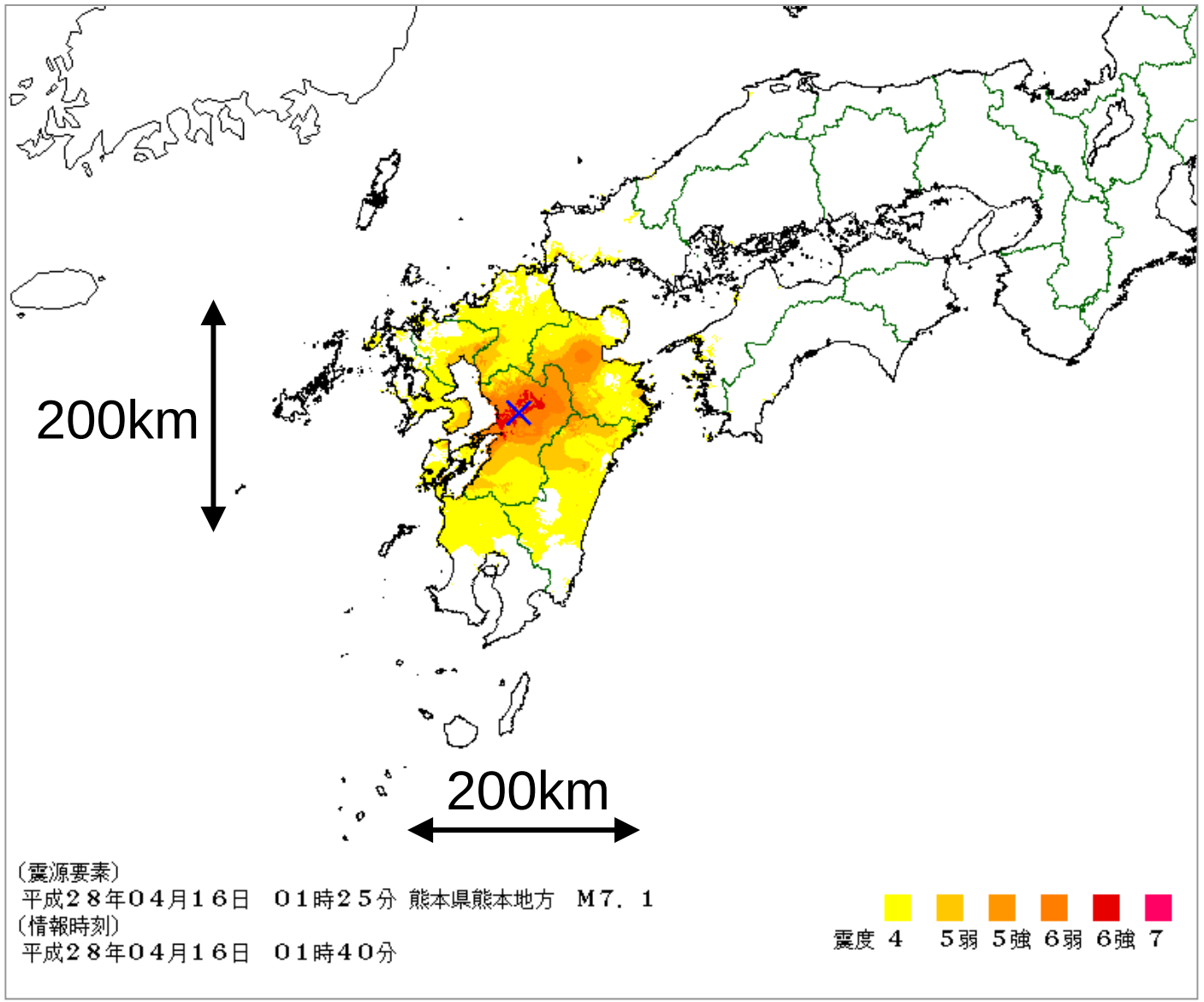
Kumamoto 2016



The great east Japan 2011

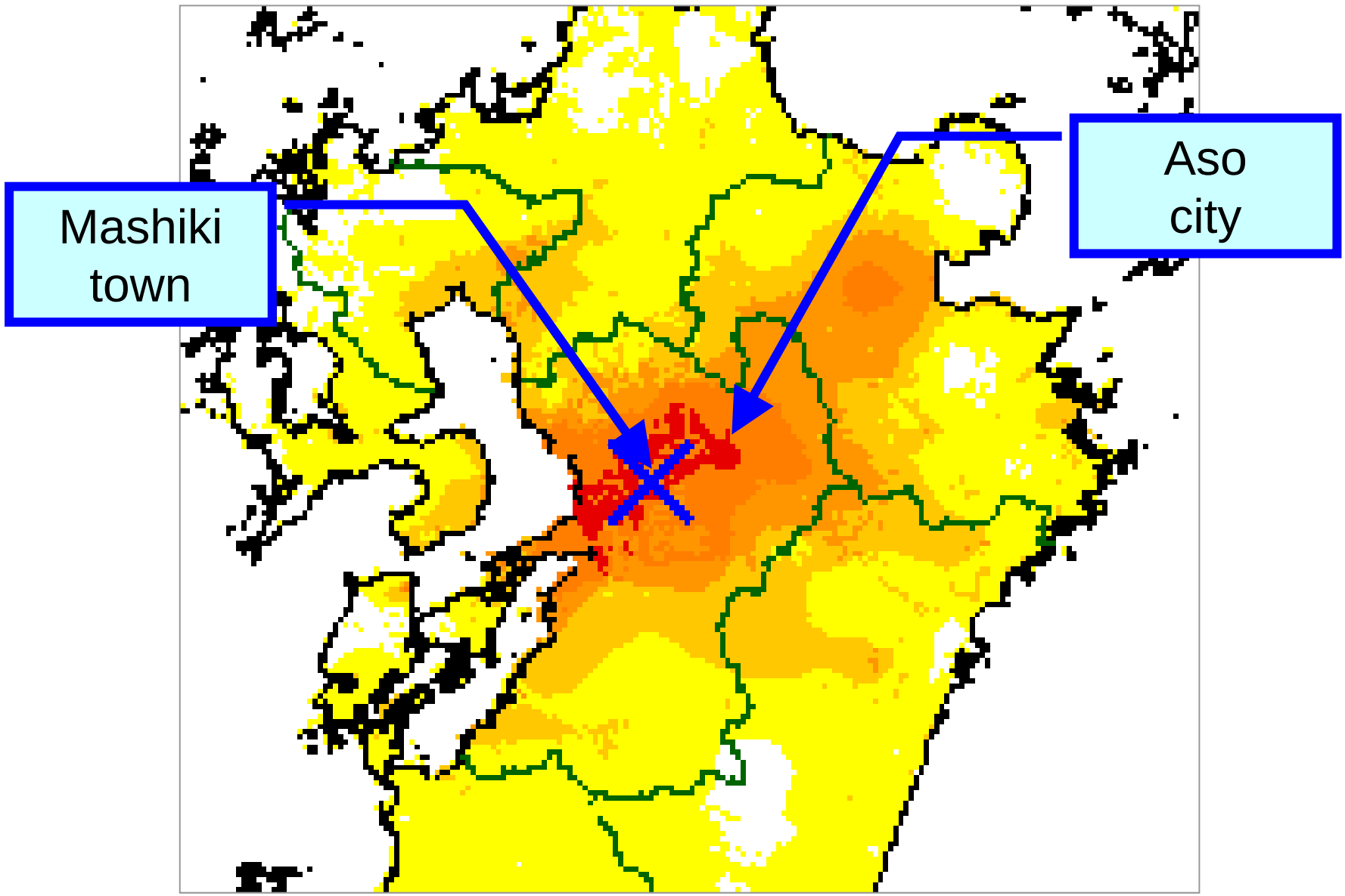
Seismic intensity map

BumpRecorder



Seismic intensity map

BumpRecorder



Damaged situation in Mashiki town

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Mashiki town is located at epicenter of Kumamoto earthquake, where has greatest damages.

Two floor house was collapse down of it's ground floor.

Damaged situation in Mashiki town

BumpRecorder

Left house was damaged and left lane closed for safety.

Damaged situation in Mashiki town

BumpRecorder

Road pavement was peeled.

Damaged situation in Mashiki town

BumpRecorder

Left house was damaged and left lane closed for safty.

Damaged situation in Aso city

BumpRecorder

Aso city is located at north east plase of epicenter.

Road was peeled about 7 km long.

Damaged situation in Aso city

BumpRecorder

Road was peeled and bump step also was generated.

Can we capture these situation by roughness measurement?

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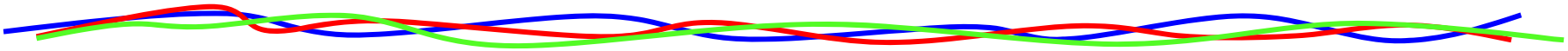
Only system in the world
Response type IRI Class 2



Measurement principle was reported
on RPUG 2014

Other response type is IRI Class 3

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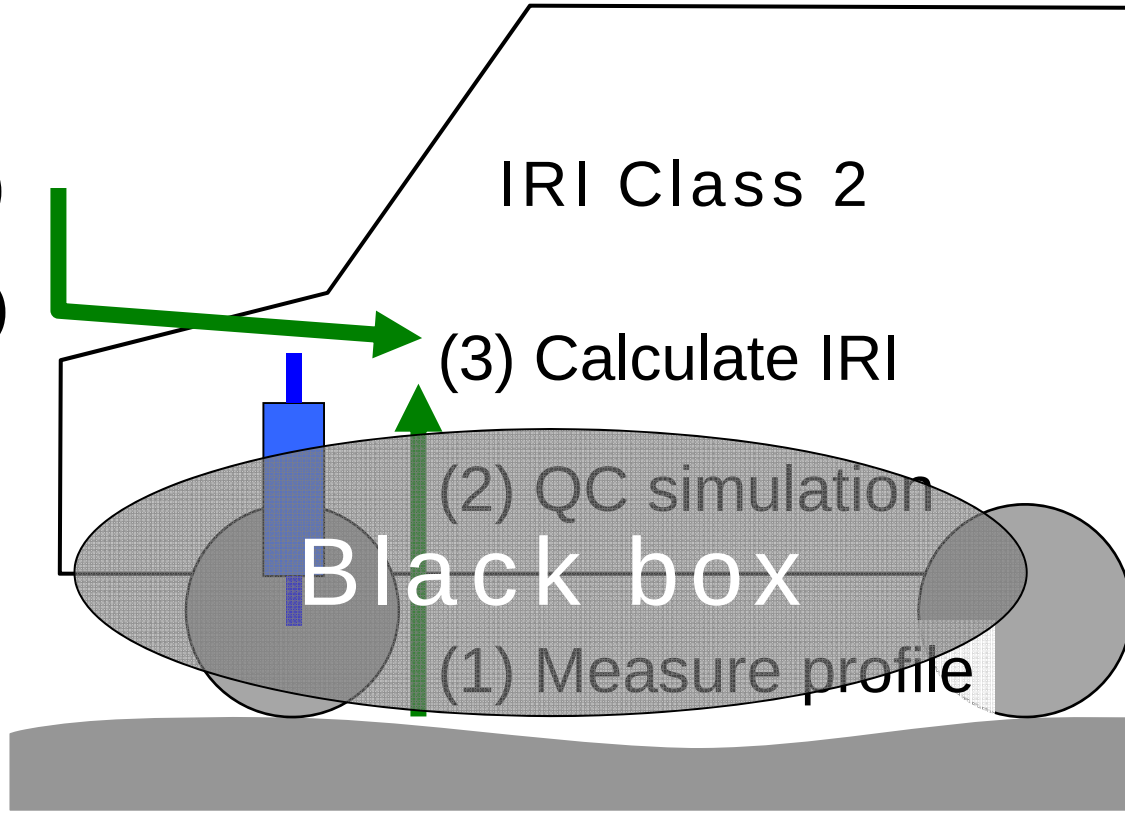
IRI Class 3

Measure acceleration (a)

Correlation formula (b)



Calibration driving is needed.

Low repeatability.

BumpRecorder is IRI Class 2

BumpRecorder

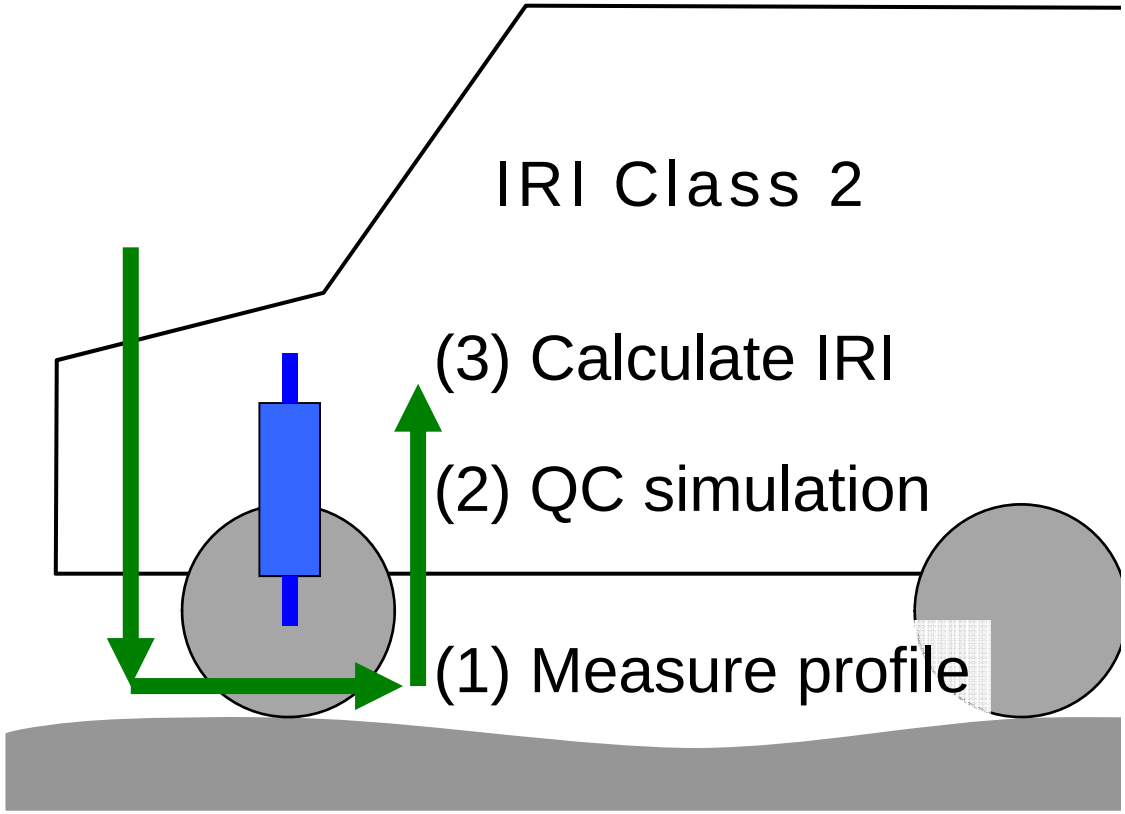
BumpRrecorder

Measure acceleration (a)

Suspension estimation (b)

Inverted QC simulation (c)

Calculate profile (d)

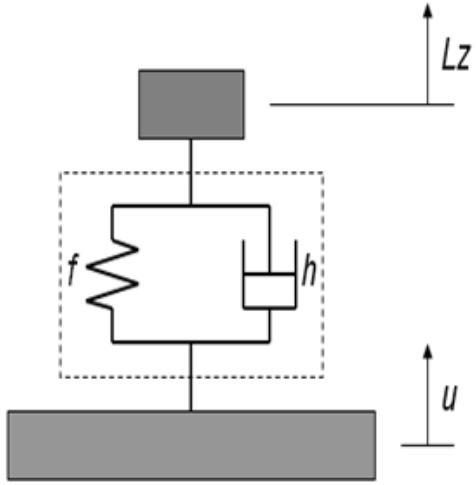


Auto calibration is done during measurement driving.

Good repeatability.

Calculate equation of motion

BumpRecorder



Suspension Spring Constant : f

FFT for vertical acceleration data

Picking up resonant frequency around 1.5Hz

Damping Ratio : h

Using FFT result and half-width method

Calculate equation of motion for 1 mass spring model
to get Unsprung movement "u"
by using sprung movement "Lz"

$$\ddot{Lz} + 2h\omega(\dot{Lz} - \dot{u}) + \omega^2(Lz - u) = 0$$ Equation of motion

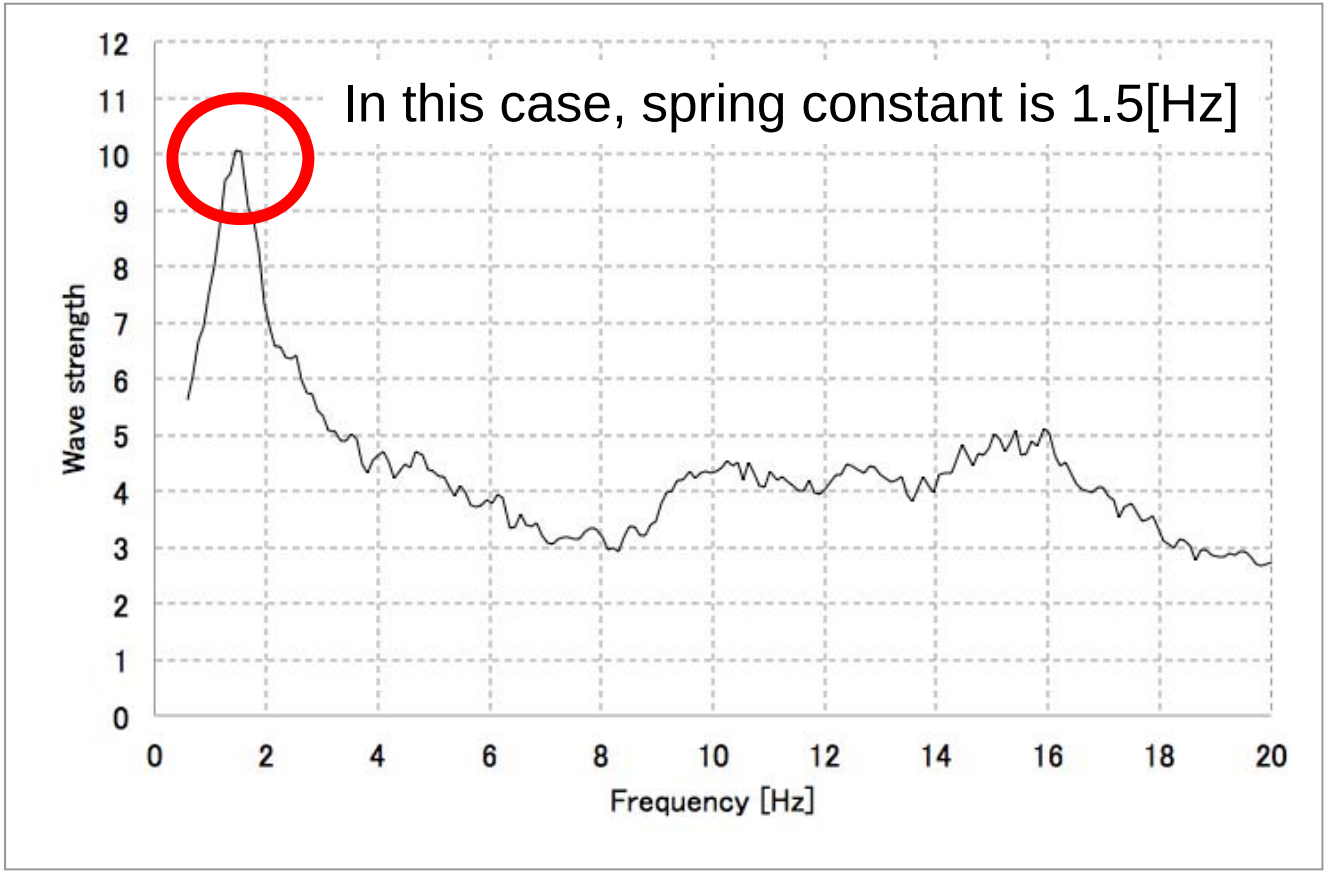
$$\omega = 2\pi f$$ Angular frequency

$$u(i) = u(i-1) + \frac{\dot{u}(i) + \dot{u}(i-1)}{2N}$$ Sum (Integlal)

Auto calibration for suspension

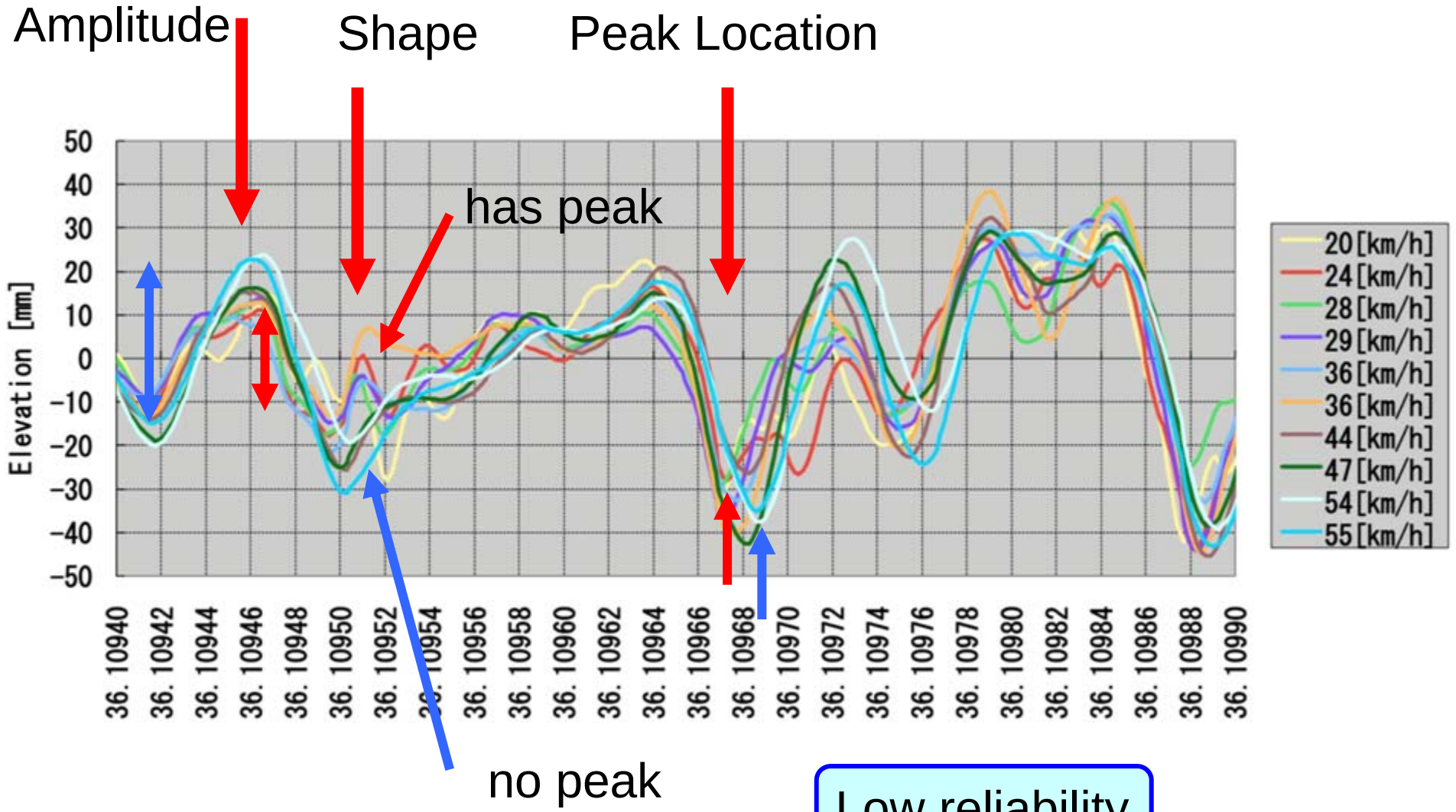
BumpRecorder

BumpRecorder automatically analyze suspensions spring constant by using frequency analysis.
It is only system in the world.



Sprung movement

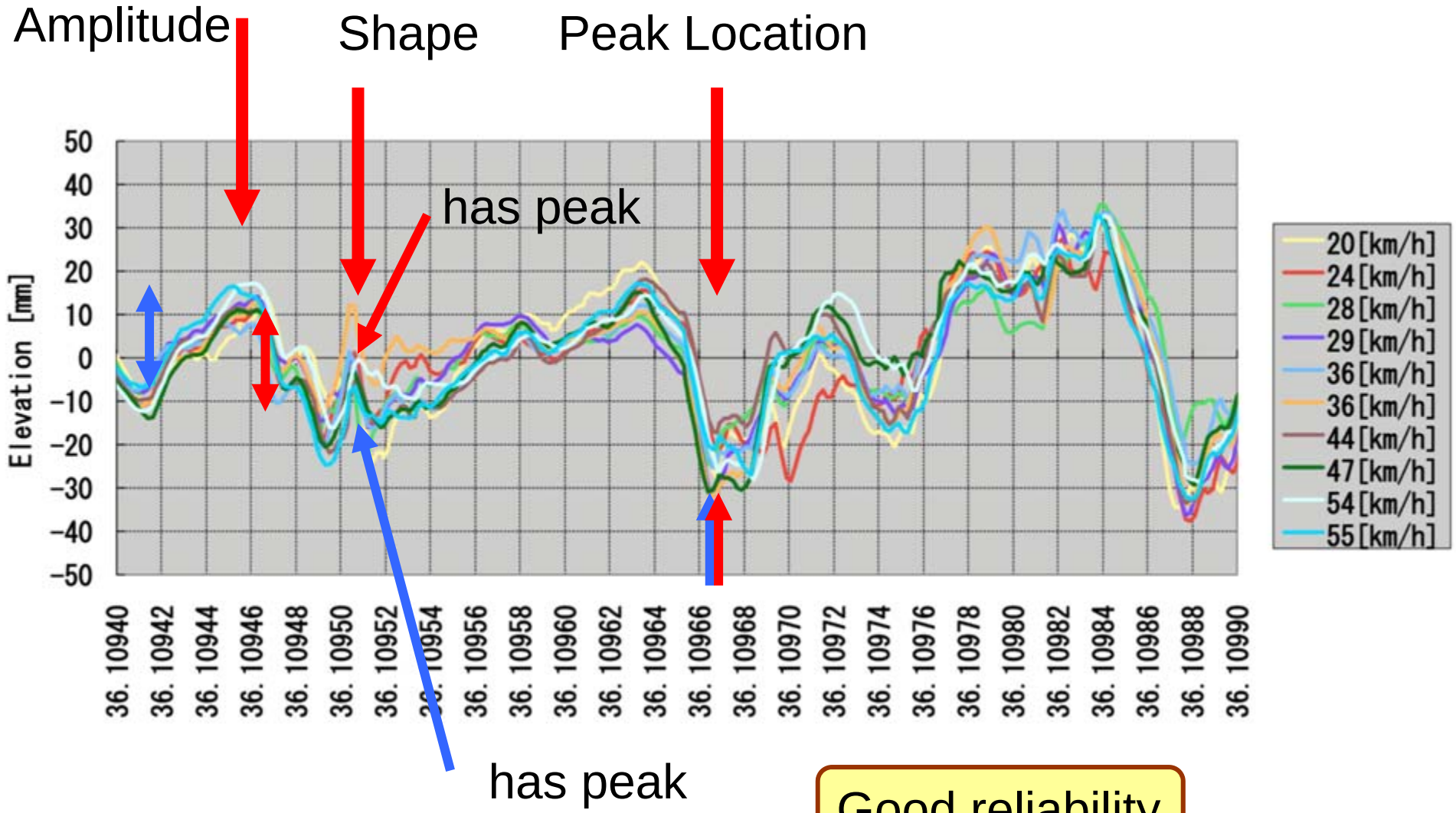
BumpRecorder



Low reliability

Unsprung elevation

BumpRecorder

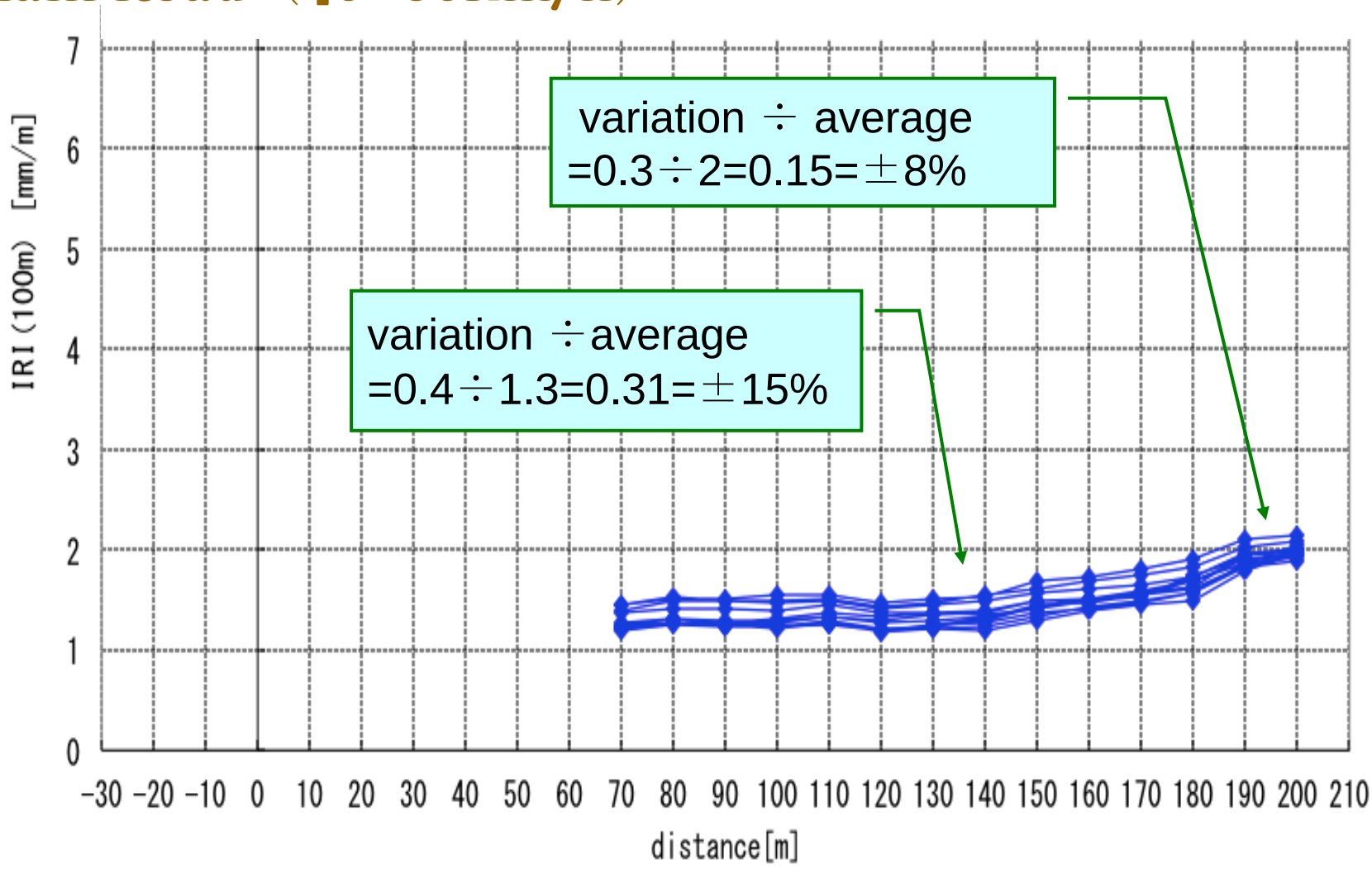


Good reliability

Repeatability

BumpRecorder

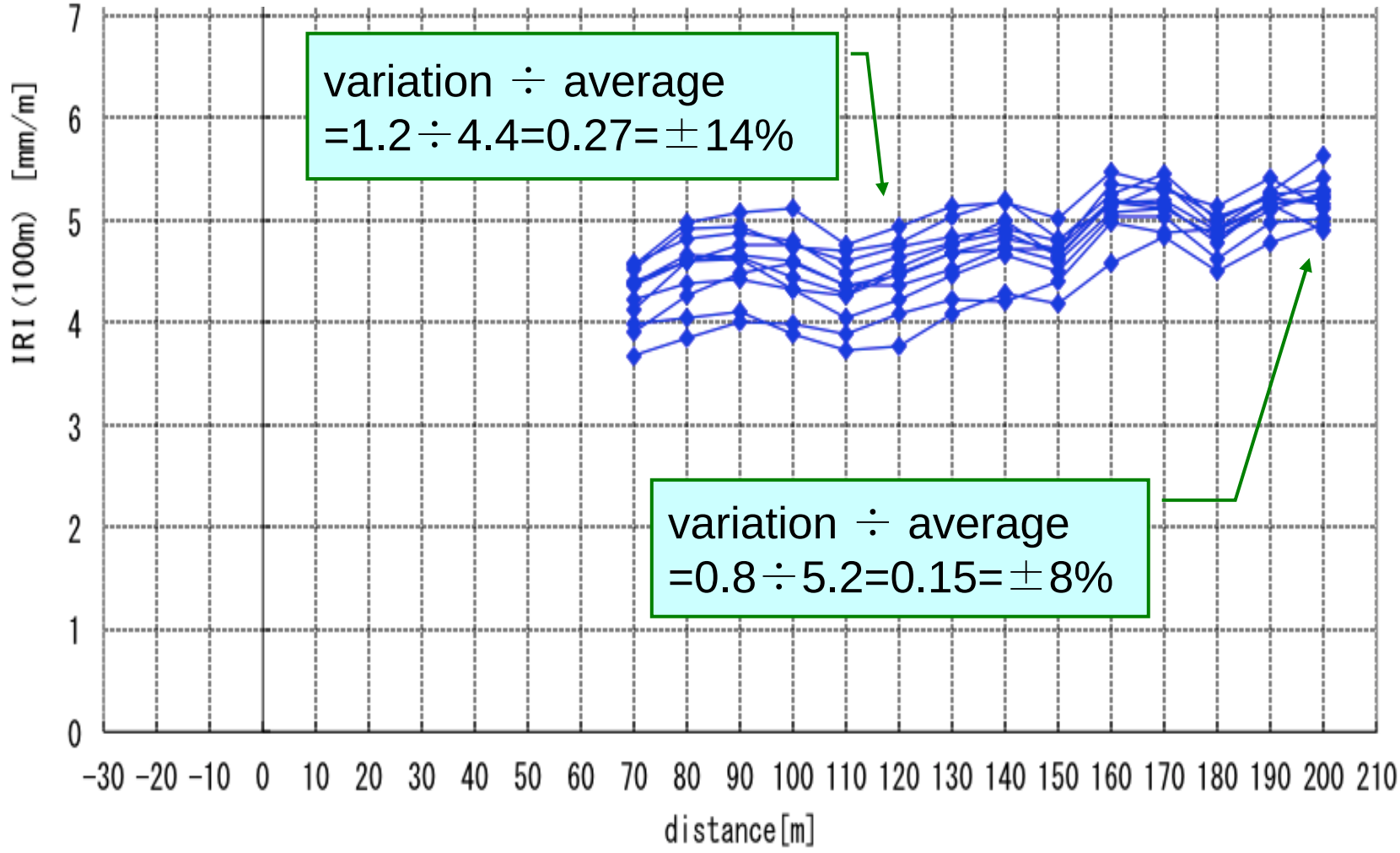
Main Road（40~60km/h）



Repeatability

BumpRecorder

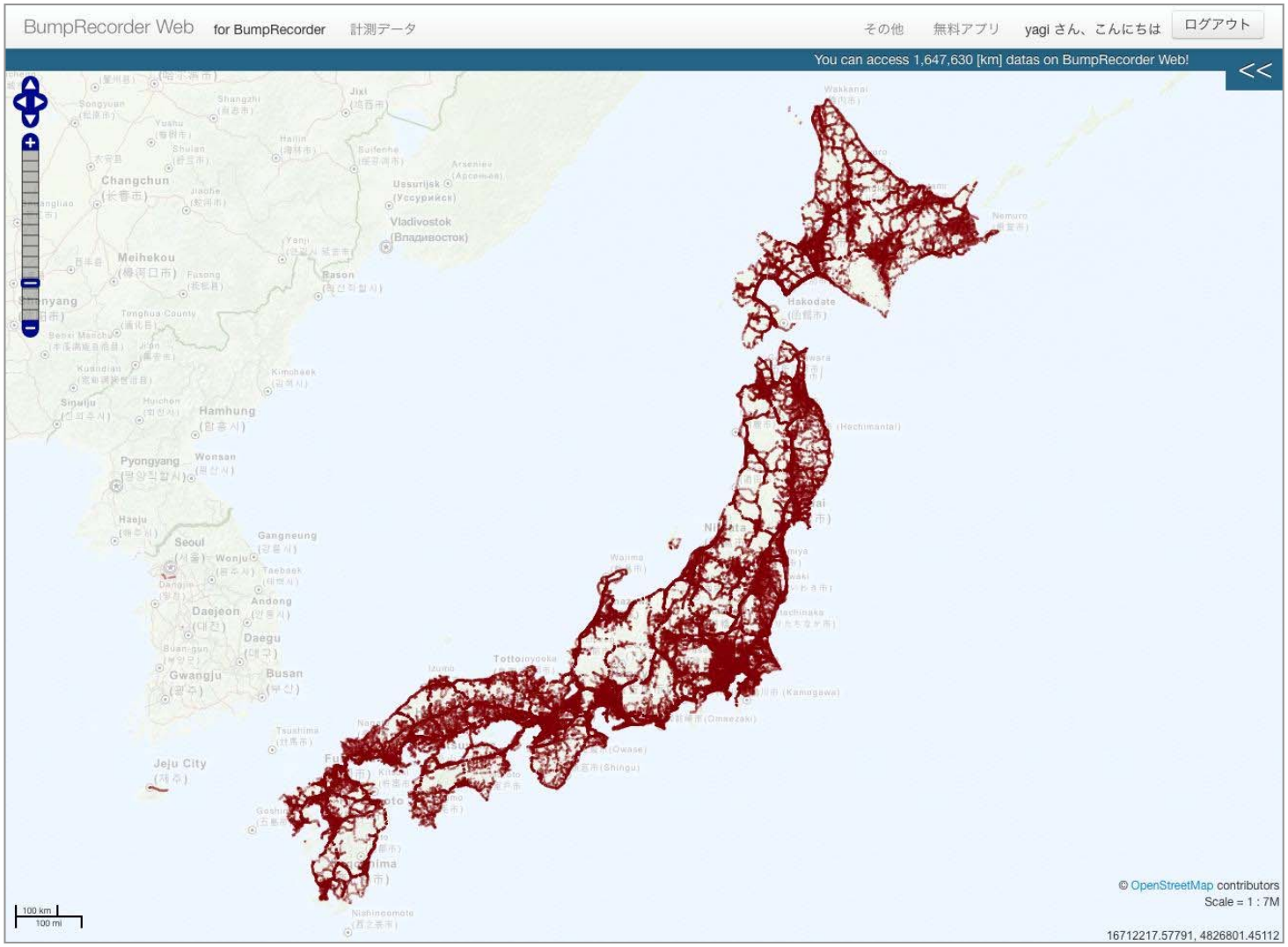
Community road （20~40km/h）



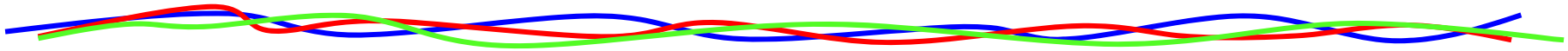
IRI measurement by **BumpRecorder**

BumpRecorder

Brown line are already measured which is almost whole Japan.



Square Mesh Section for IRI section determination



IRI Section

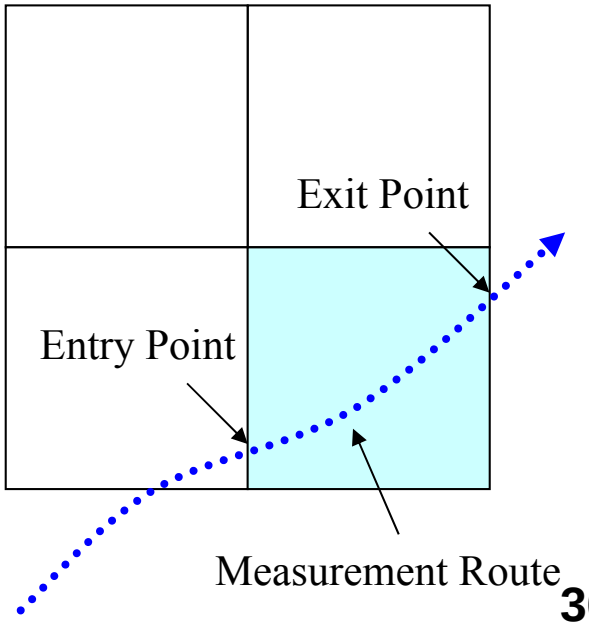
BumpRecorder

Current Problems

Usually, IRI is calculated for the section that is defined by each road location markers.
But it is difficult to make this information.

Proposed Method (**BumpRecorder** is using this section)

Square Mesh grid is defined on the earth by latitude and longitude.
When the measurement route cross over this grid, from the entry point to the exit point are the section for IRI calculation.



Square Mesh Code

BumpRecorder

North South length and East West length of Square Mesh are same. And basic size is 1/8192 deg(1/2^13) that is about 10m.

Basic Mesh size

LonCode =

$w = int(lon / 8192)$

$e = w + 1$

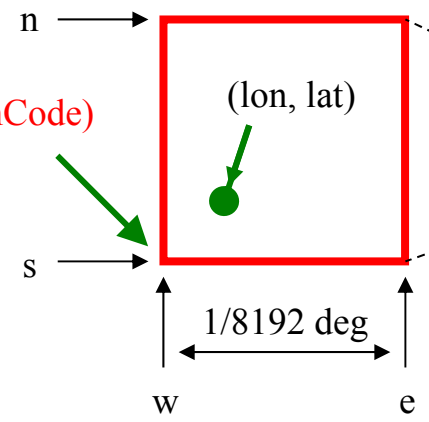
LatCode =

$s = int(\int(1/\cos(lat)) * \alpha)$

$= int(LOG((1+\sin(lat)) / (1-\sin(lat))) / 2 * \alpha)$

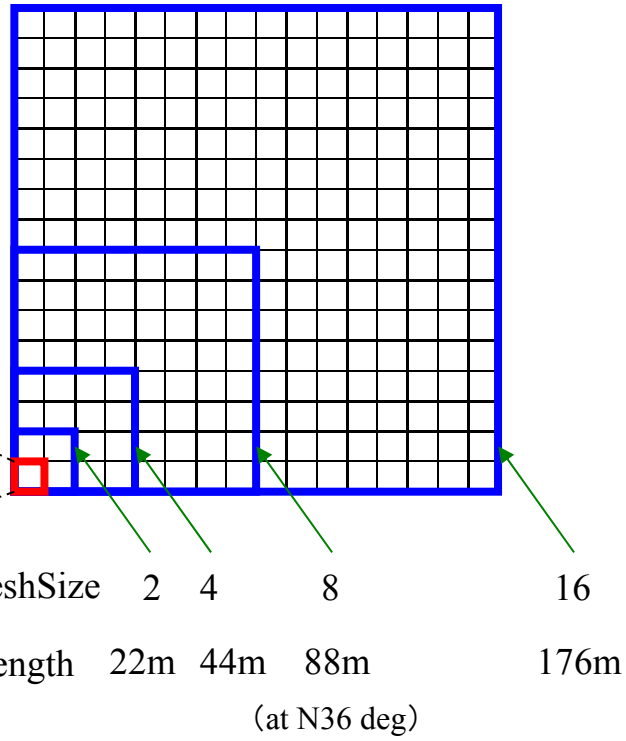
$n = s + 1$ $\alpha=469367.1$

Mesh Code is defined by (MeshSize, LatCode, LonCode)



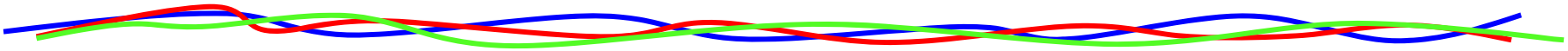
Expand Mesh size

Mesh size is defined by x2, x4, x8, x16 …



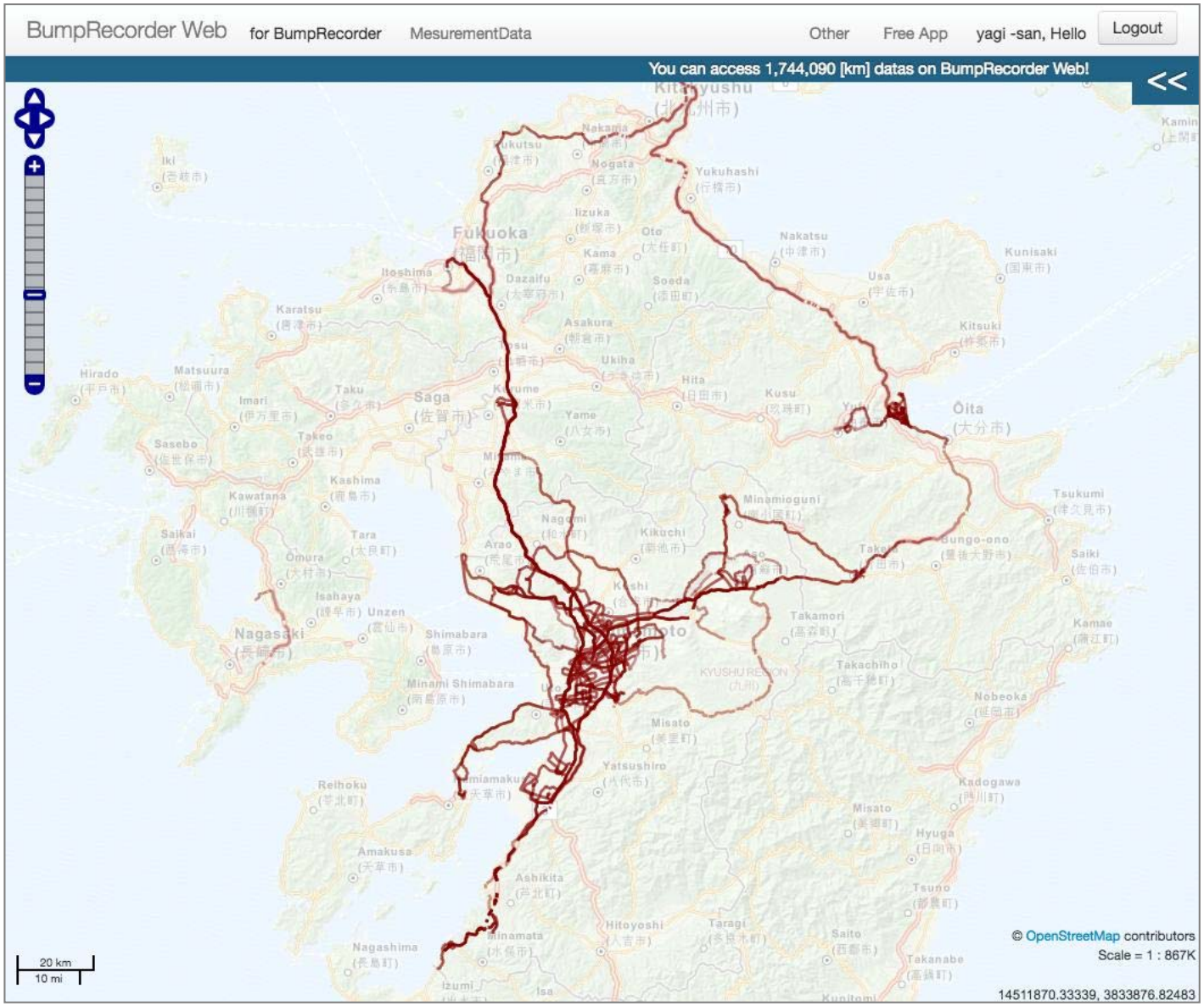
* BumpRecorder Web is calculating IRI for Mesh Size 2, 4, 8, 16...
* Depending on driving route, IRI section length is different between neighboring sections.

Measurement Results



Research distance up to 3,400km

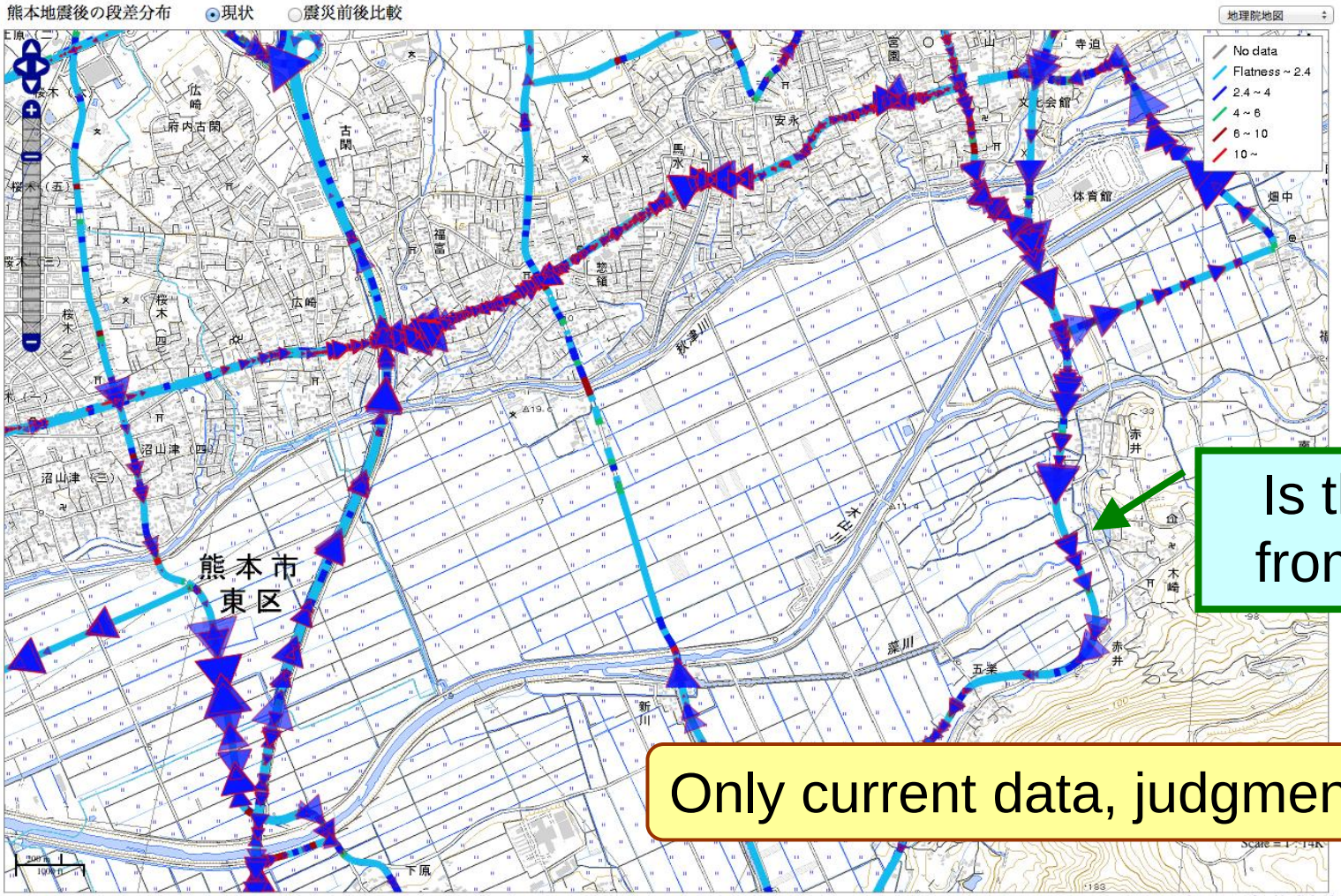
BumpRecorder



Current roughness status

BumpRecorder

Line color and triangular shows road roughness and bump step.
All bump step are affects from quake?

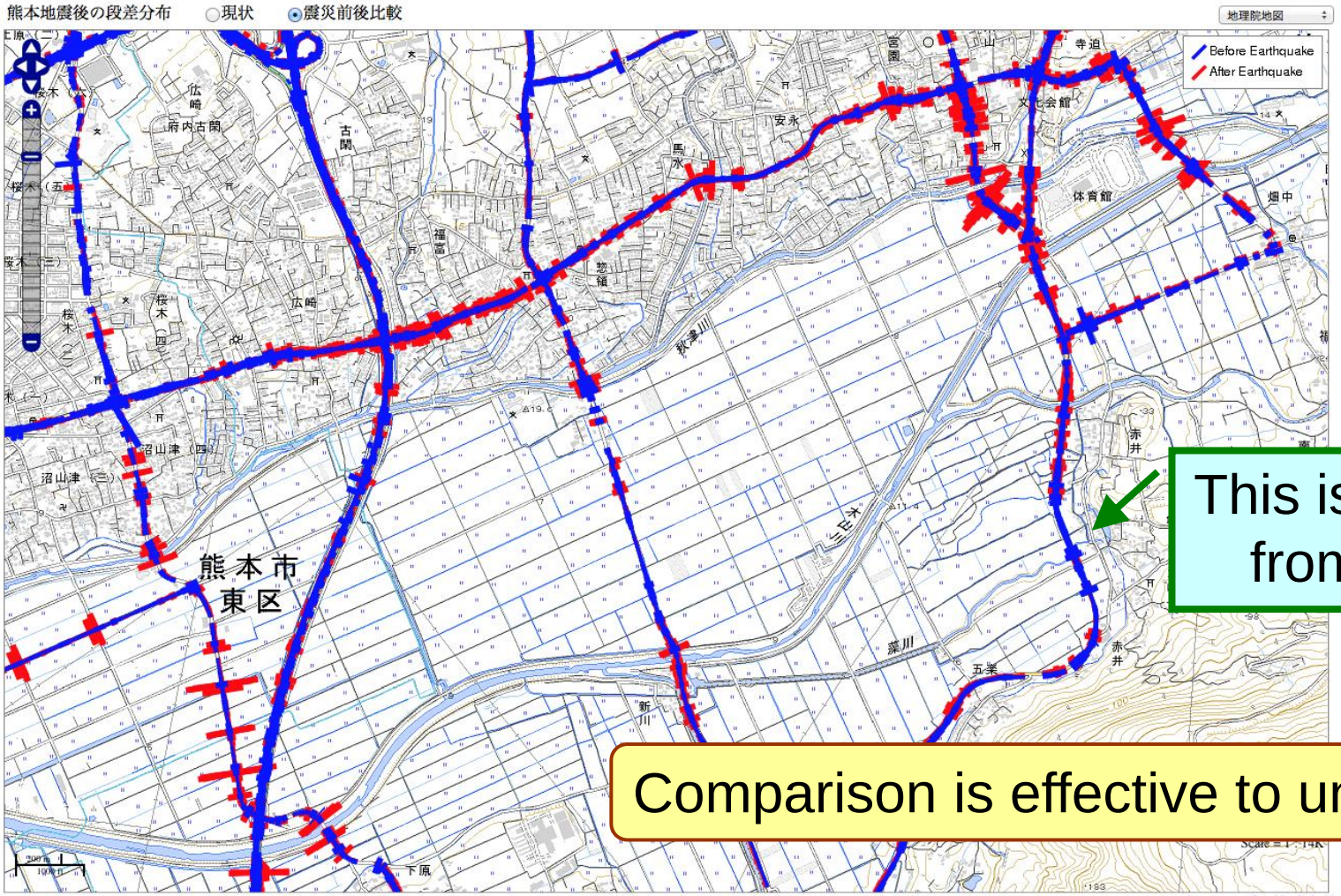


Roughness comparison, before and after

BumpRecorder

Blue line shows roughness before the earthquake.

Red line shows after quake.



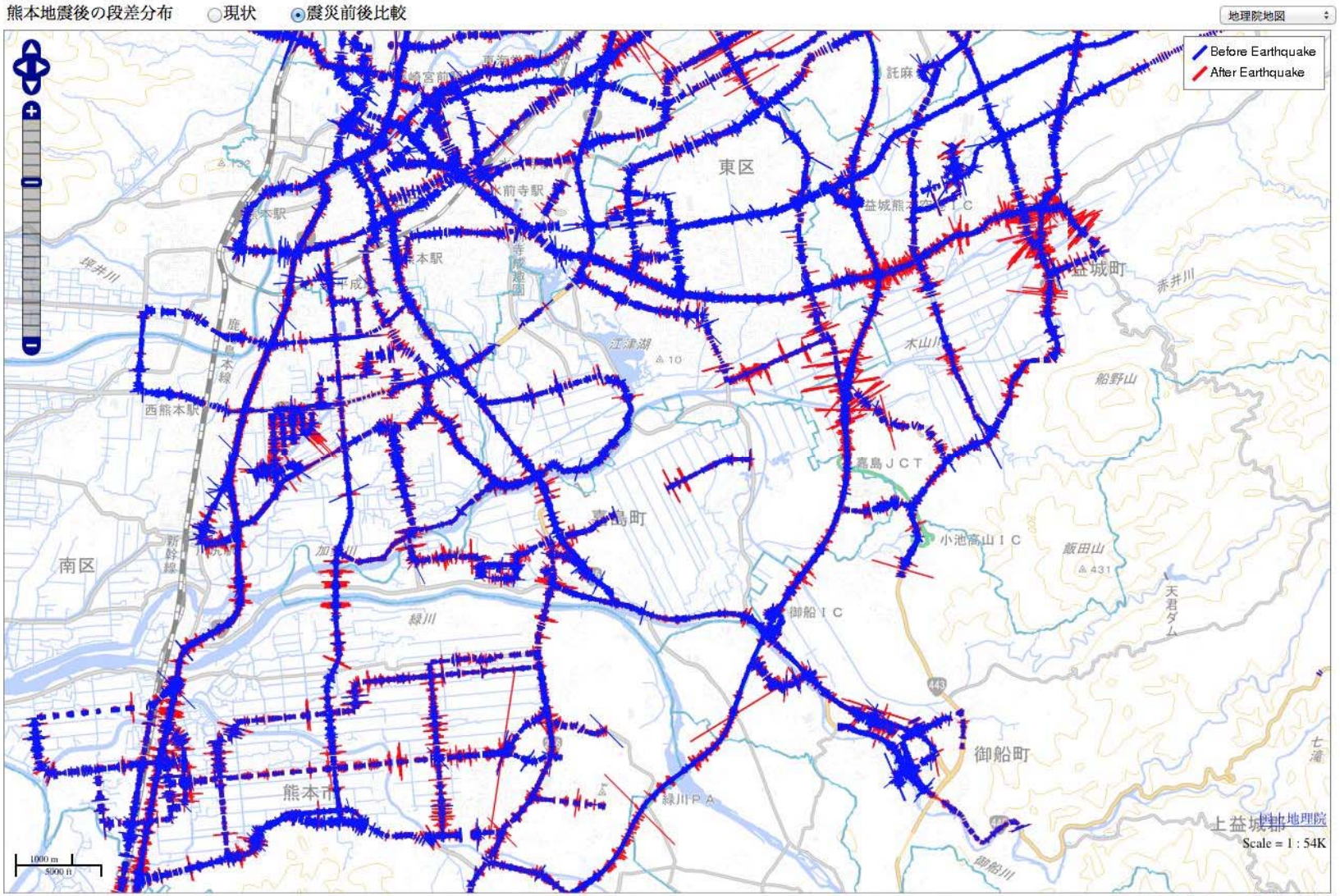
This is not affect from quake.

Comparison is effective to understand.

Roughness distribution around Mashiki Town

BumpRecorder

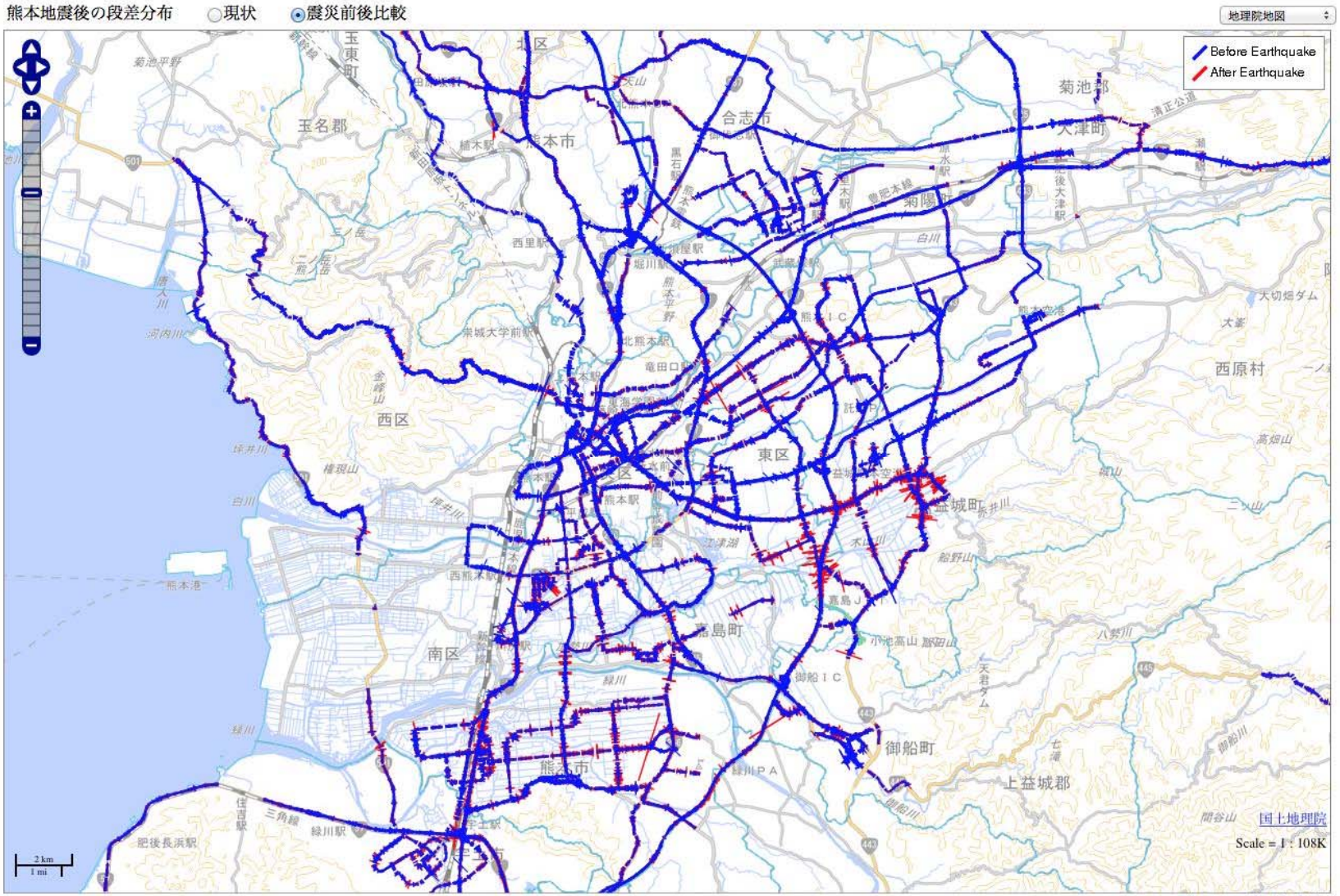
Mashiki Town has terrible damages.



Wide area roughness distribution

BumpRecorder

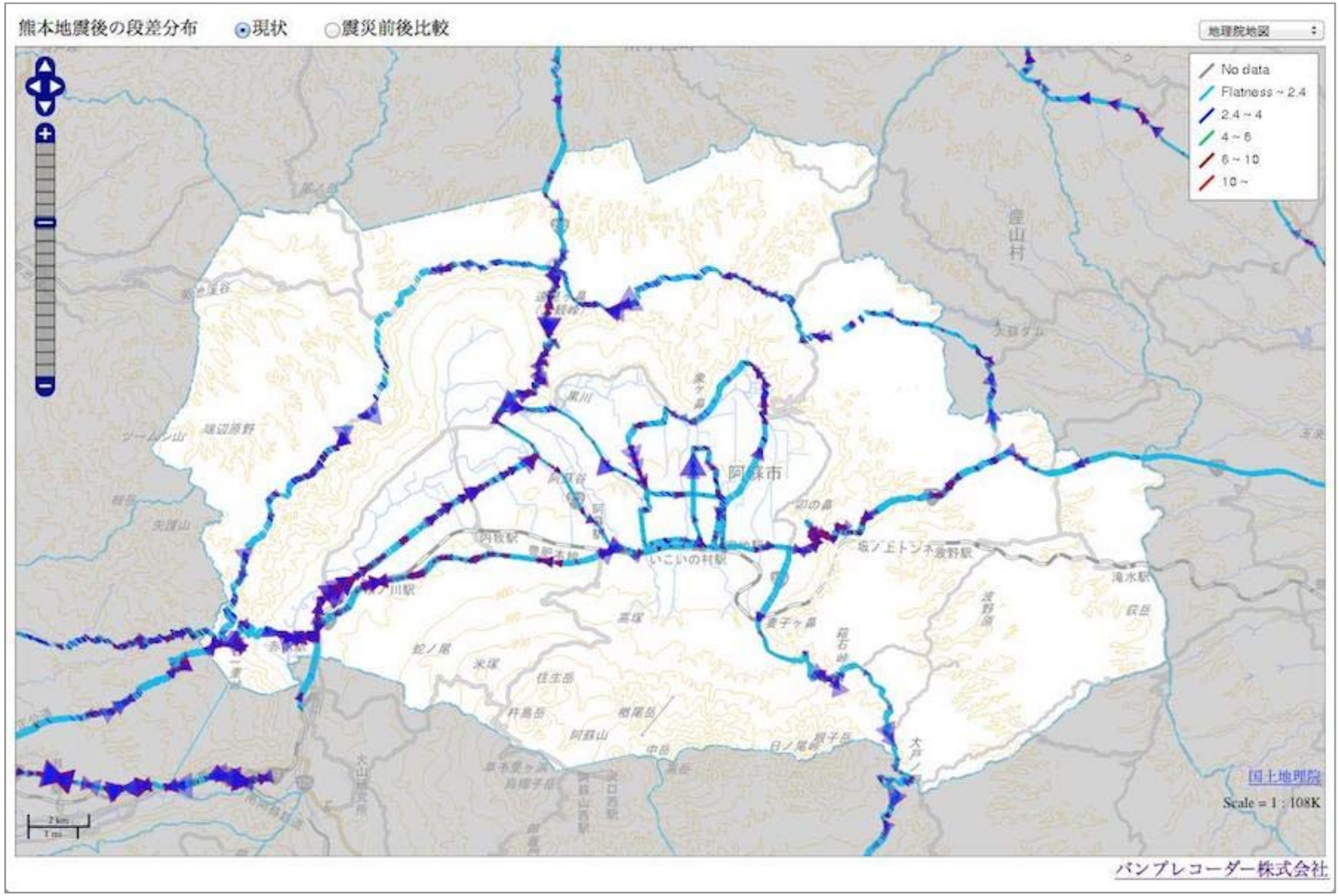
Damages are spreading to south west direction.



Roughness measurement at Aso city

BumpRecorder

Main road can be measured after the earthquake.



Comparison for before and after in Aso

BumpRecorder

Comparison can not done unless before data.

Regular survey is an important !

Conclusions

BumpRecorder

- After Kumamoto earthquake, roughness measurement was done by using smartphone.
- It can measure 3,400km in 1 week.
- Before and after roughness comparison is effective to understand road damages.
- Not only after data, but also before data is an important to understand roughness changes.
- It means that regular measurement is an important.
- Response type measurement is bringing regular roughness measurement.
- I believe that it becomes popular in a near future.

Question(s)?

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