BumpRecorder

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

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Earthquake Situations

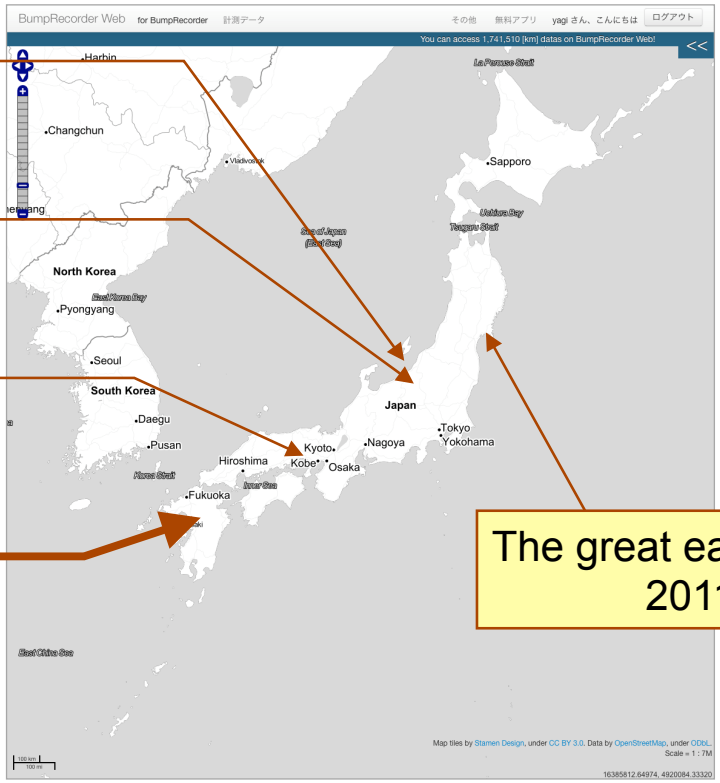
Past Earthquake in Japan

Chuetu oki 2007

Chuetu 2004

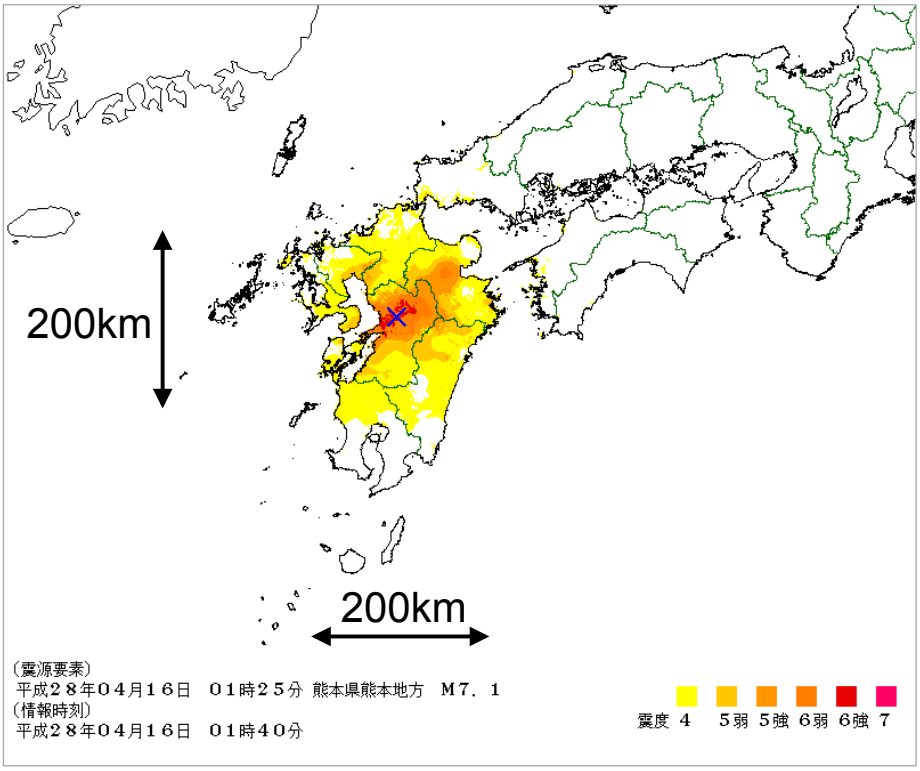
Kobe 1995

Kumamoto 2016

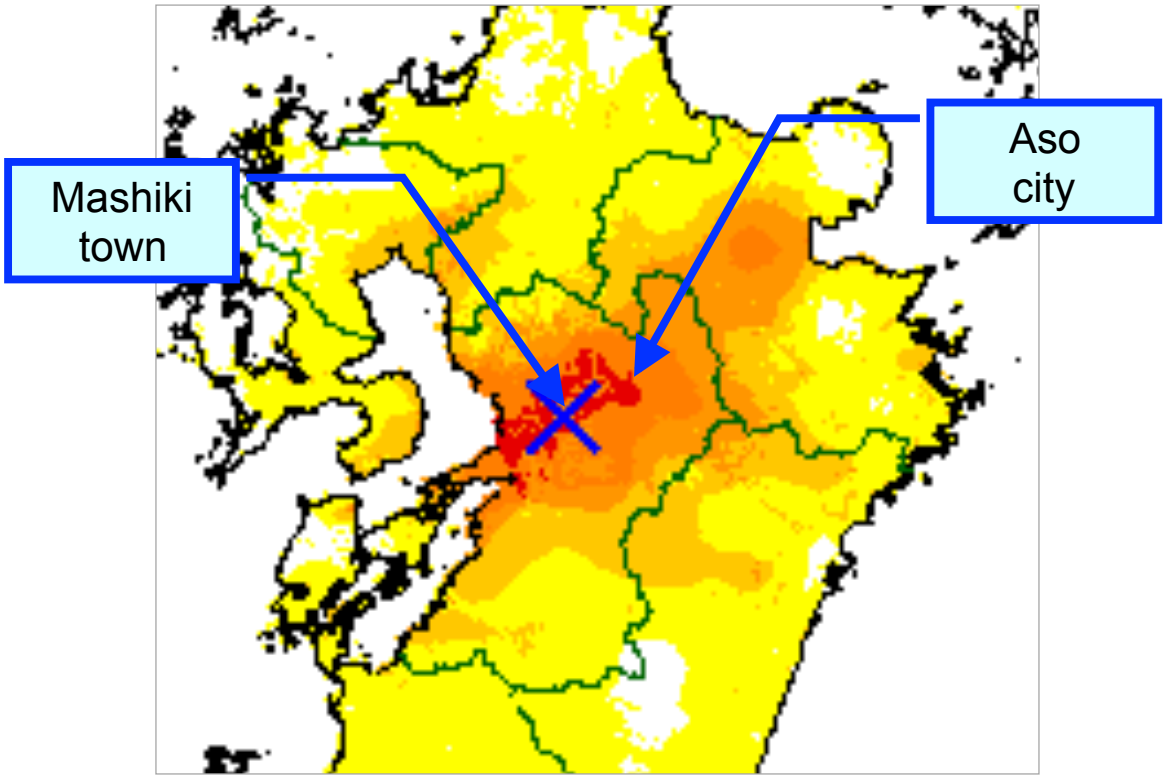


The great east Japan 2011

Seismic intensity map



Seismic intensity map



Damaged situation in Mashiki town

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

Left house was damaged and left lane closed for safety.

Damaged situation in Mashiki town

Road pavement was peeled.

Damaged situation in Mashiki town

Left house was damaged and left lane closed for safty.

Damaged situation in Aso city

Aso city is located at north east plase of epicenter.

Road was peeled about 7 km long.

Damaged situation in Aso city

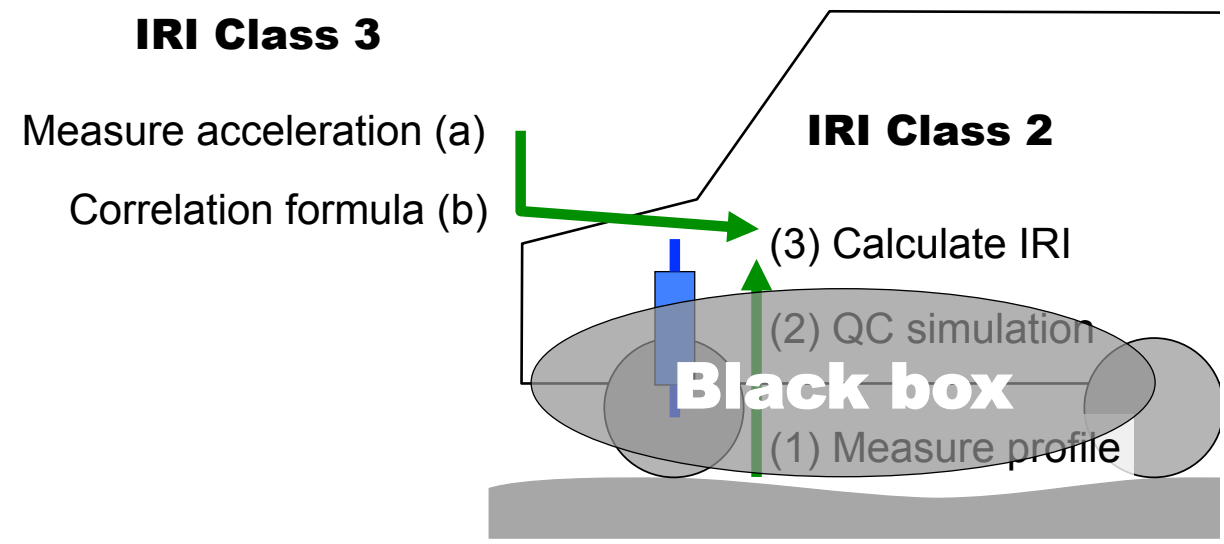
Road was peeled and bump step also was generated.

Can we capture these situation by roughness measurement?

BumpRecorder
Only system in the world
Response type IRI Class 2

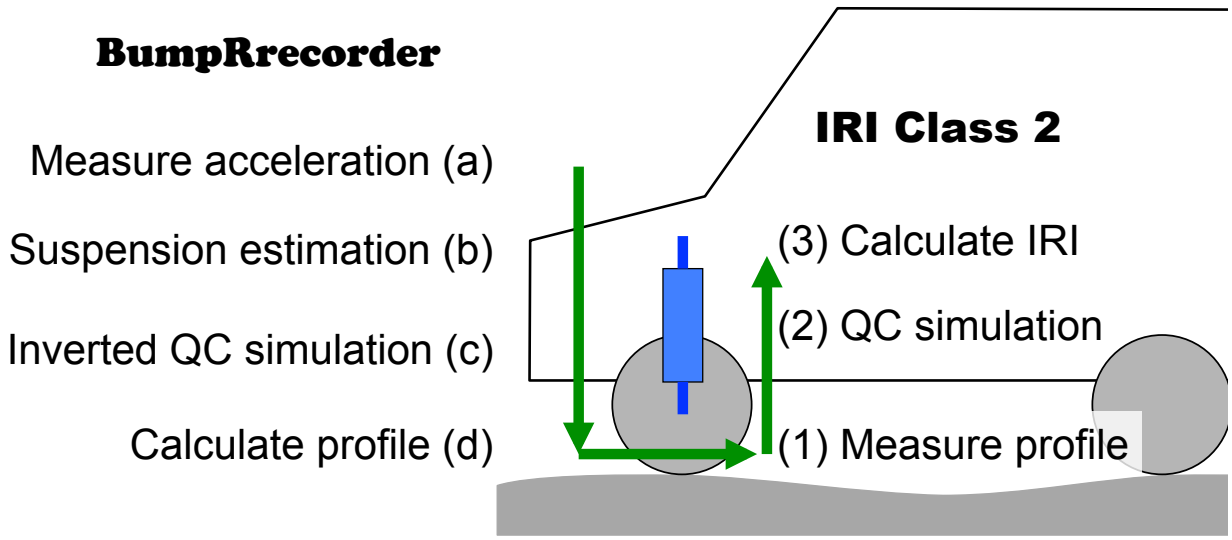
Measurement principle was reported
on 1st IRF Asia Regional Congress

Other response type is IRI Class 3



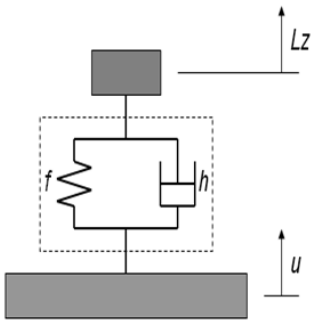
Calibration driving is needed.
Low repeatability.

BumpRecorder is IRI Class 2



Auto calibration is done during measurement driving.
Good repeatability.

Calculate equation of motion



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"

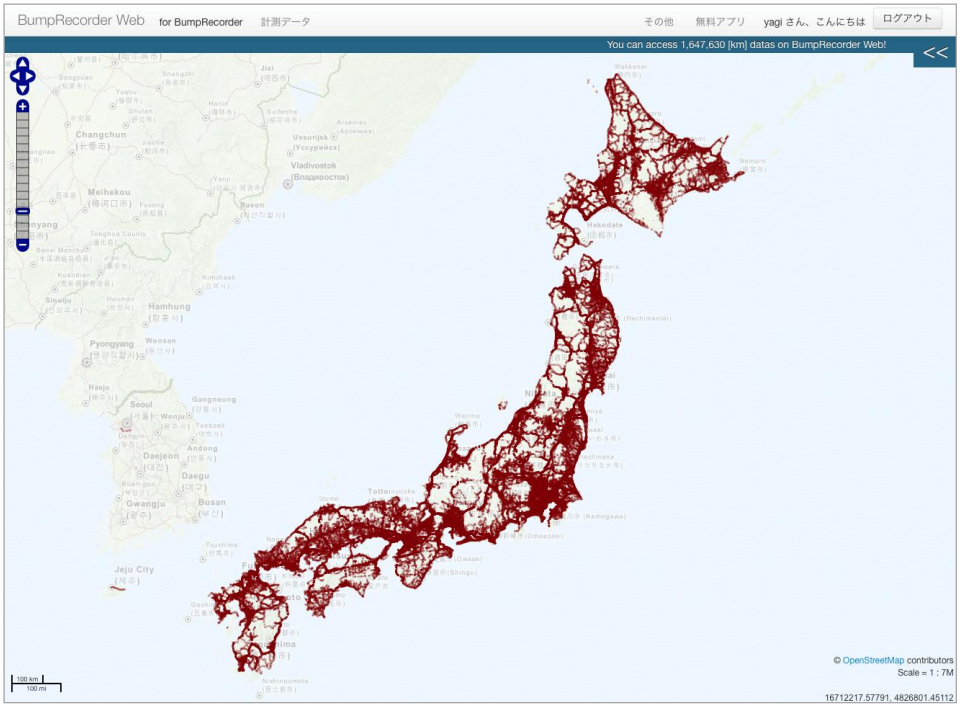
$$\ddot{Lz} + 2h\omega(\dot{Lz} - \dot{u}) + \omega^2(Lz - u) = 0$$ Equation of motion

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

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

IRI measurement by BumpRecorder

Brown line are already measured which is almost whole Japan.



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Square Mesh Section for IRI section determination

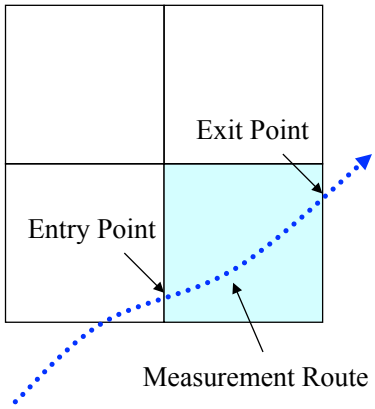
IRI Section

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

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)

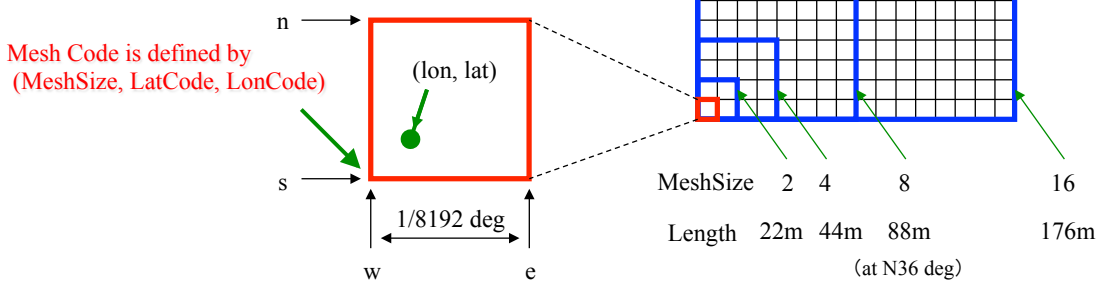
e = w + 1

LatCode =

s = int(∫(1/cos(lat)) *α)

= int(LOG((1+sin(lat)) / (1-sin(lat))) / 2 *α)

n = s + 1 α=469367.1



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.

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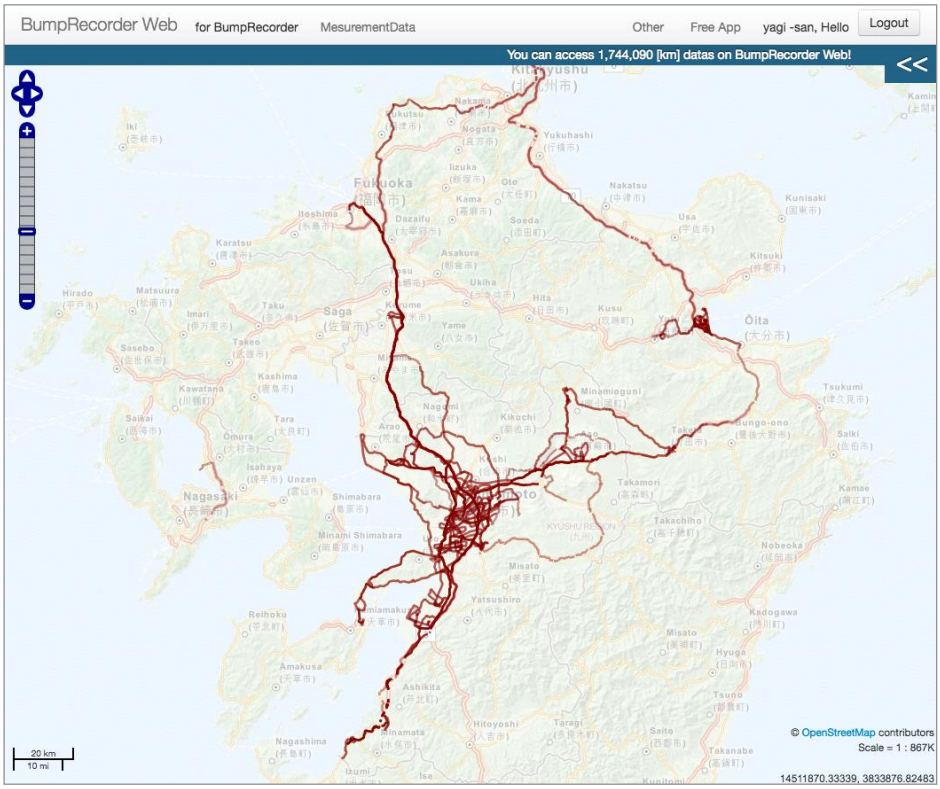
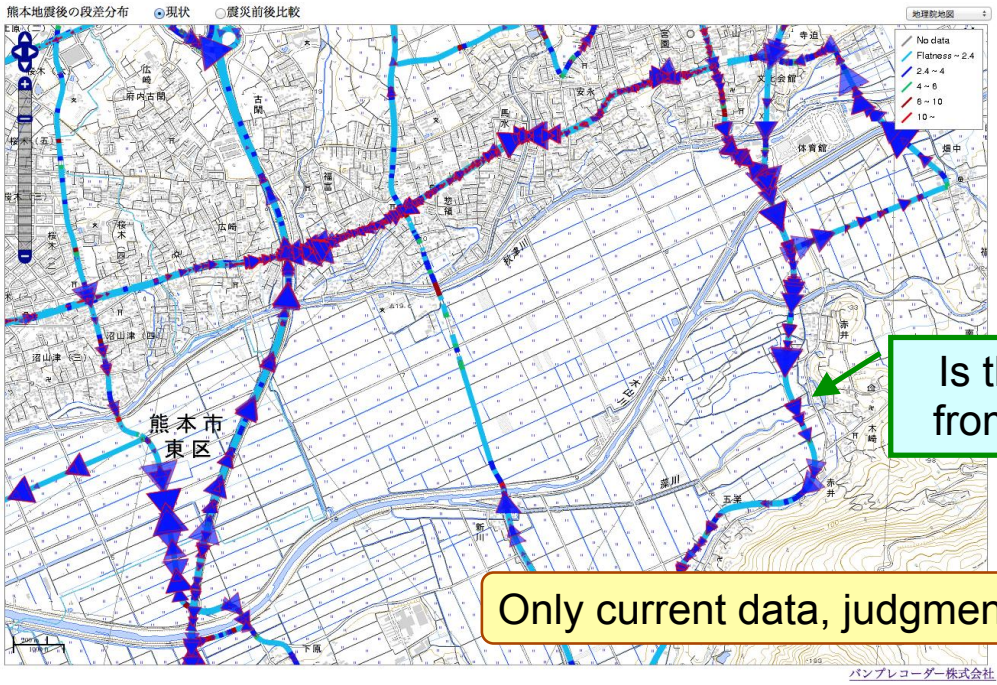
Measurement Results

Research distance up to 3,400km



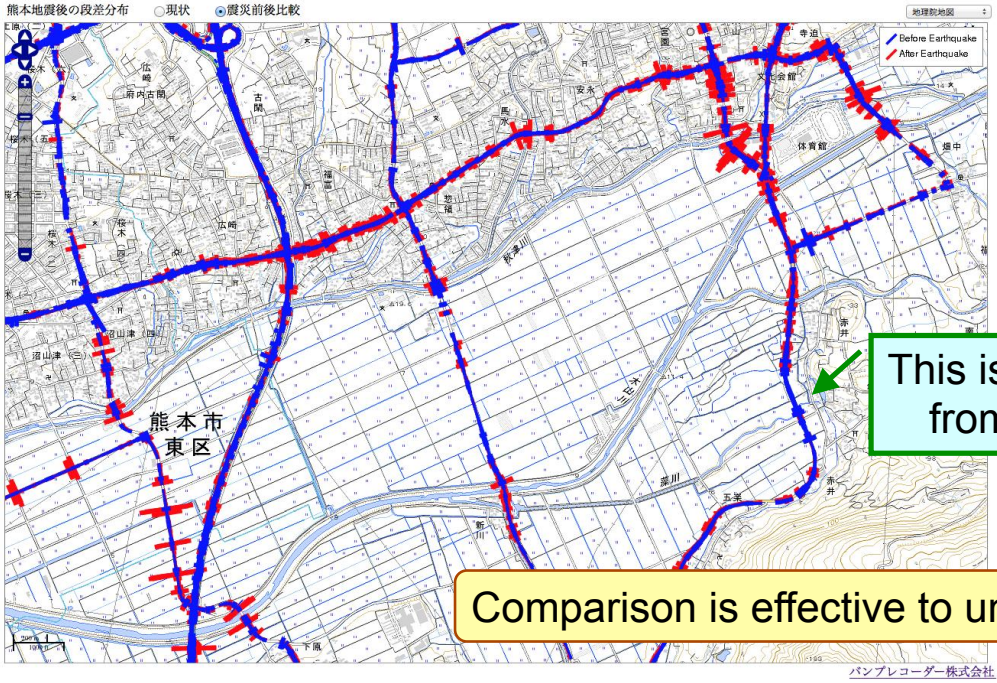
Current roughness status

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



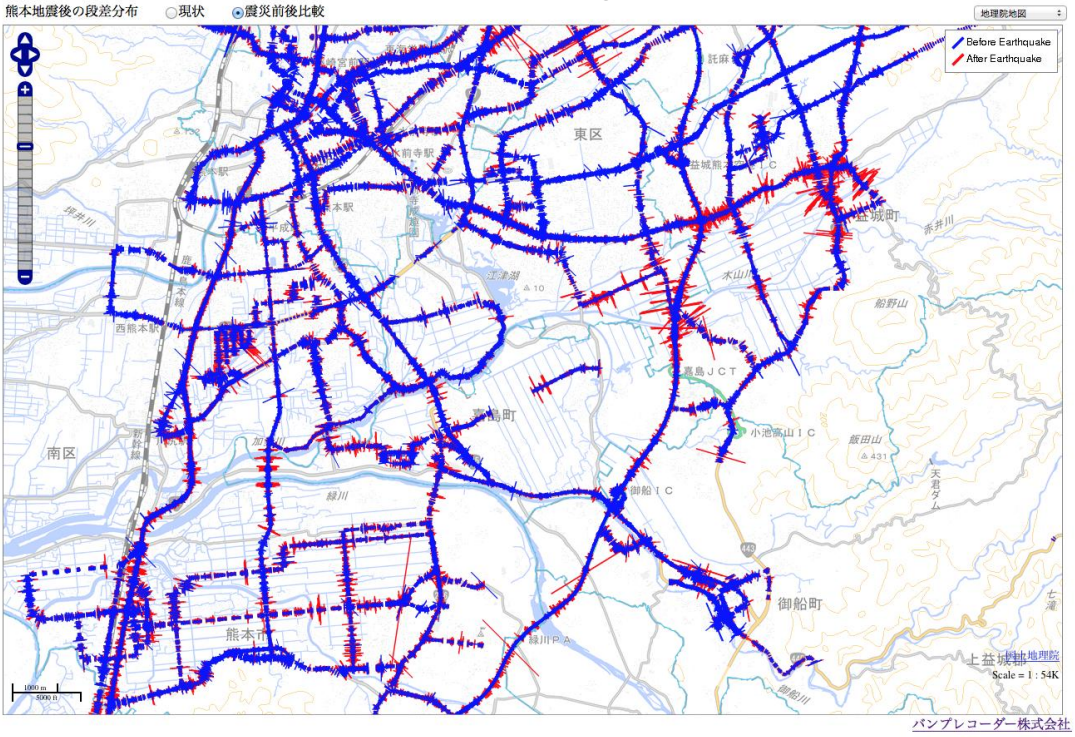
Roughness comparison, before and after

Blue line shows roughness before the earthquake.
Red line shows after quake.



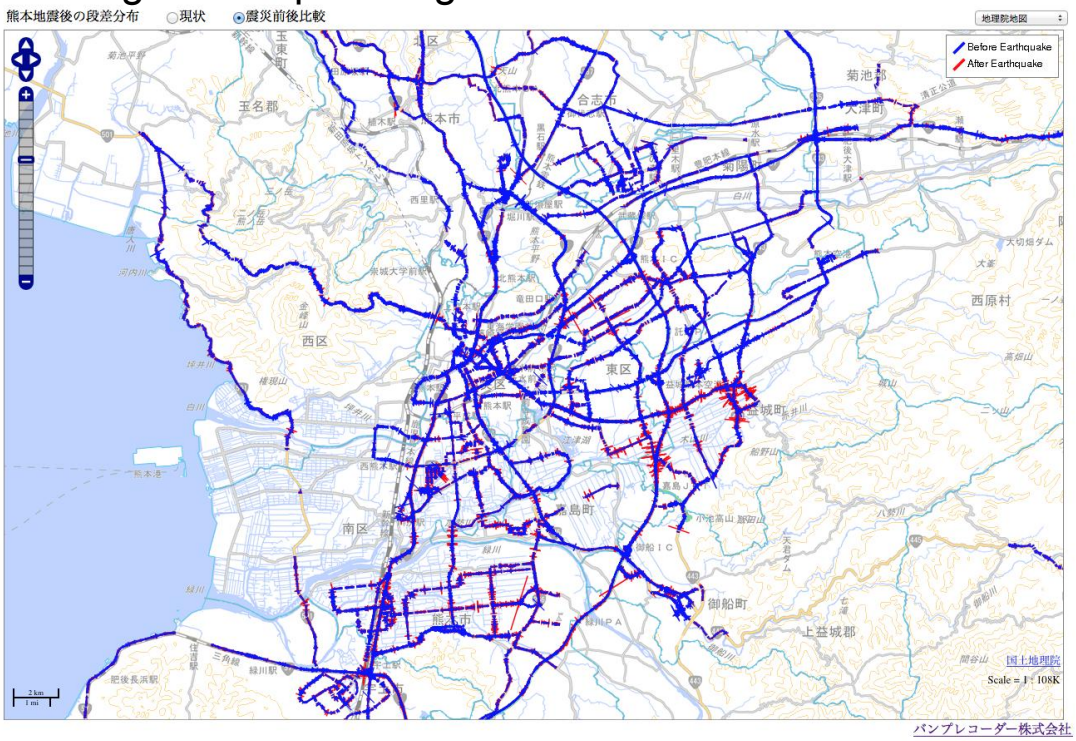
Roughness distribution around Mashiki Town

Mashiki Town has terrible damages.



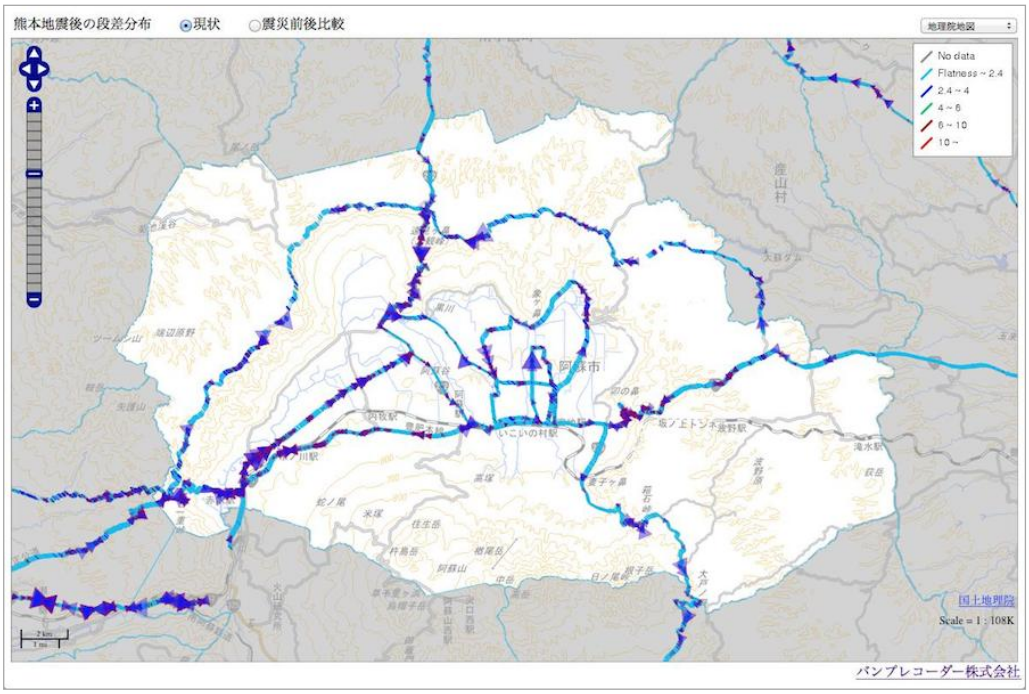
Wide area roughness distribution

Damages are spreading to south west direction.



Roughness measurement at Aso city

Main road can be measured after the earthquake.



Comparison for before and after in Aso

Comparison can not done unless before data.

Conclusions

- 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.

2016/11/18

Question(s)?

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