KURAMA-II and the Environmental Radiation Survey in Fukushima

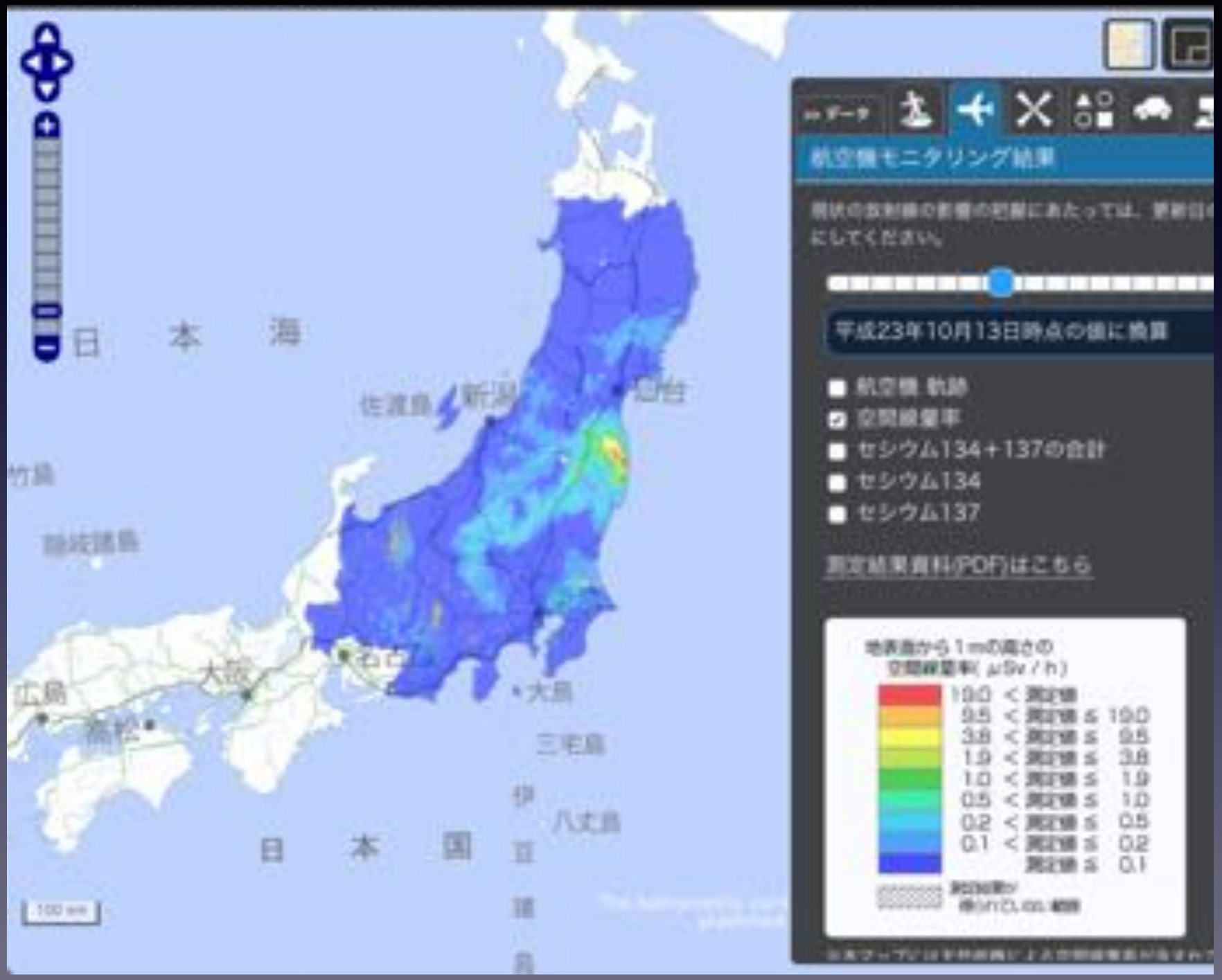
Minoru Tanigaki
Research Reactor Institute, Kyoto University

My Talk

- Backgrounds
- Outline of KURAMA/KURAMA-II
- What we have done with KURAMA/KURAMA-II
- Ongoing challenges with KURAMA-II

Backgrounds

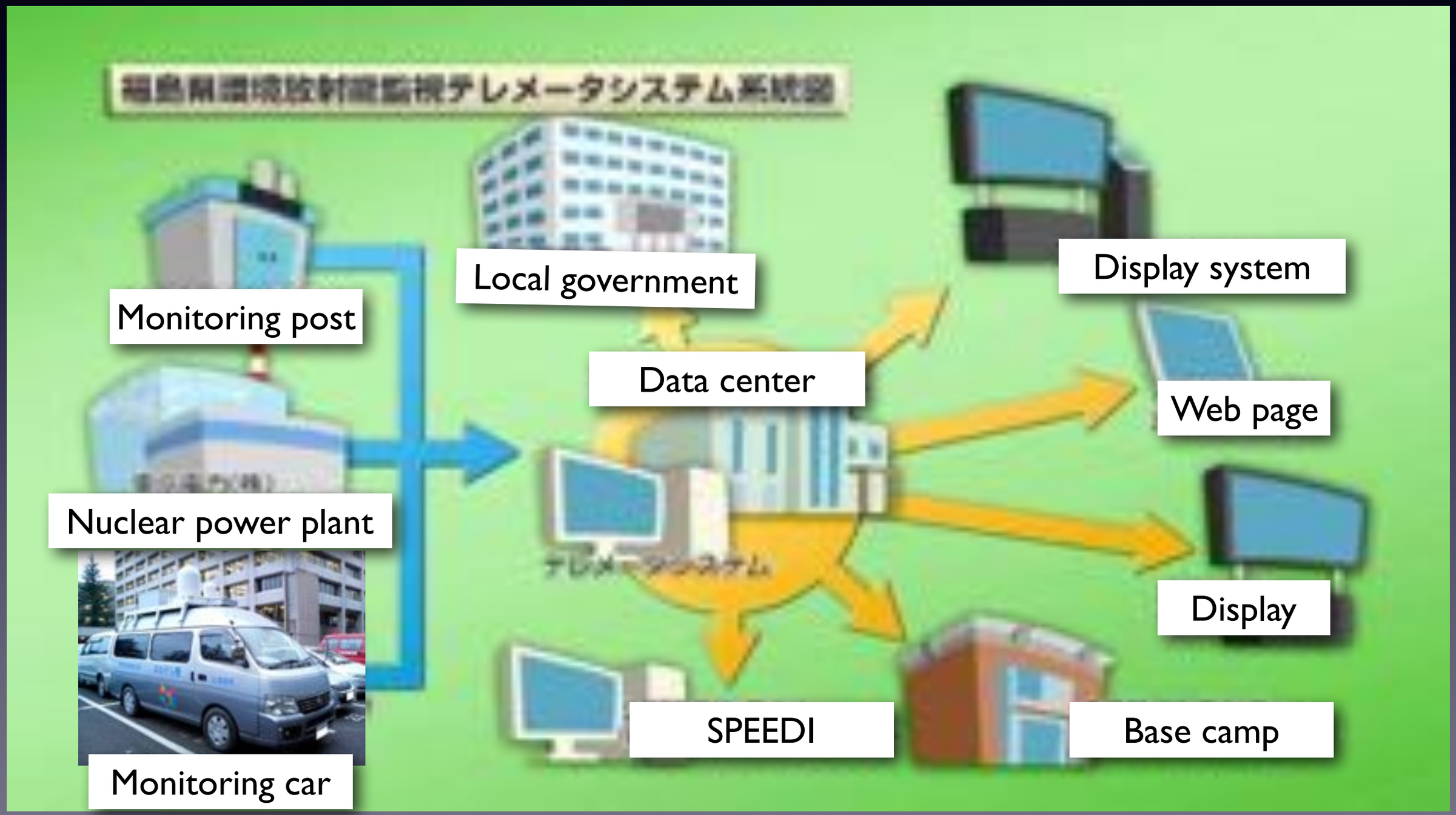
Nuclear Accident in Fukushima



http://ramap.jmc.or.jp/map/eng/

Monitoring Scheme in Fukushima

A typical centralized system



Monitoring Scheme in Fukushima

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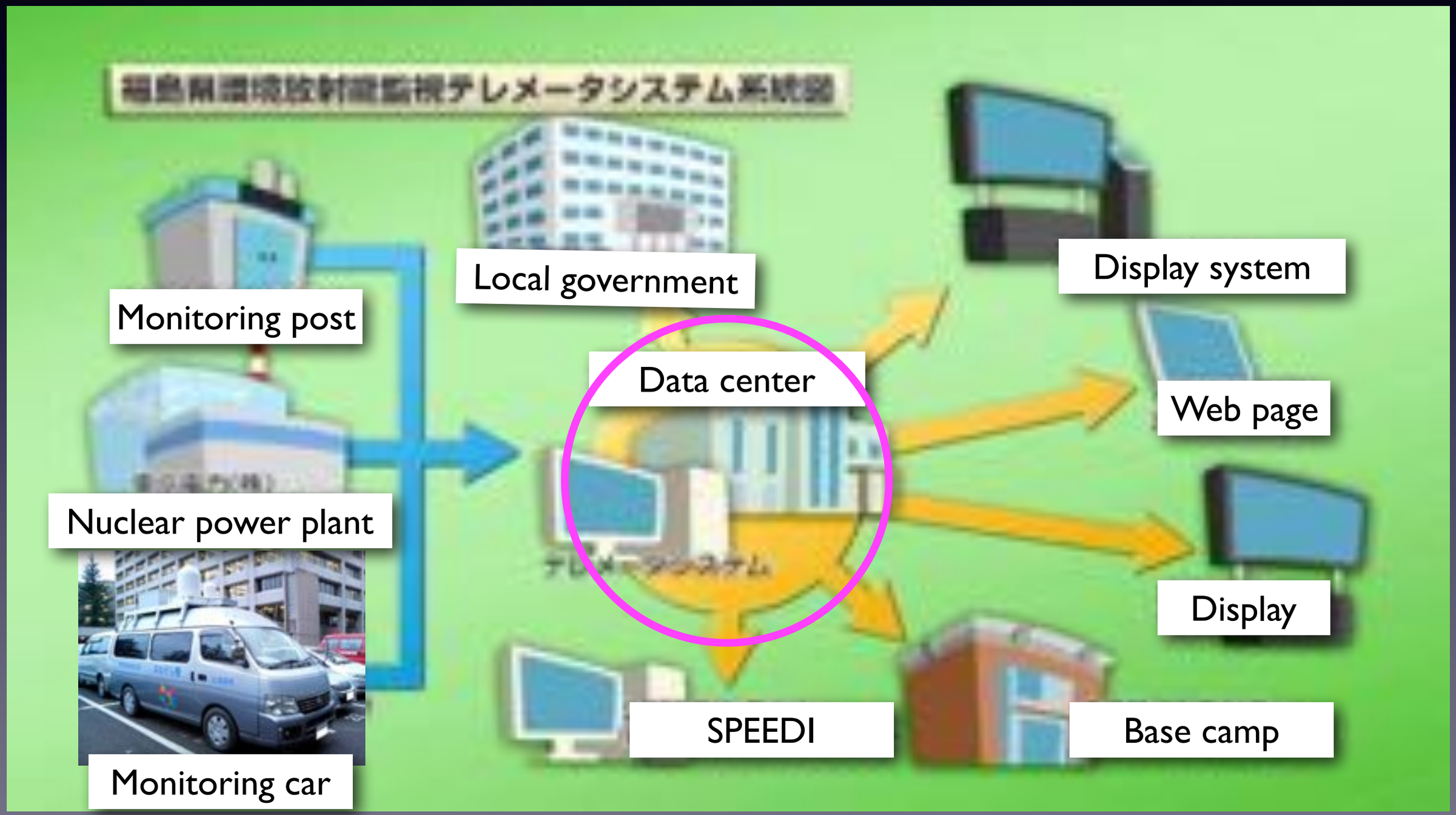
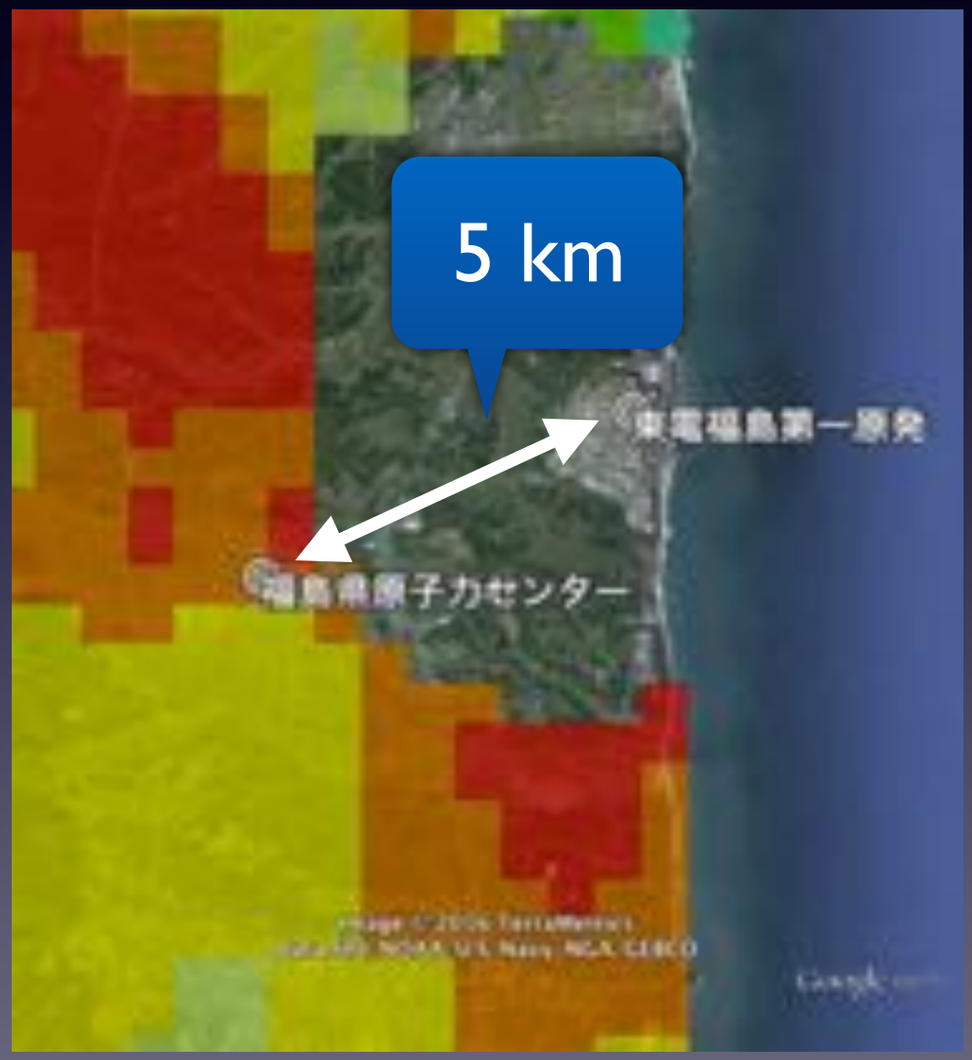


Nuclear Accident in Fukushima

Critical damage on monitoring scheme

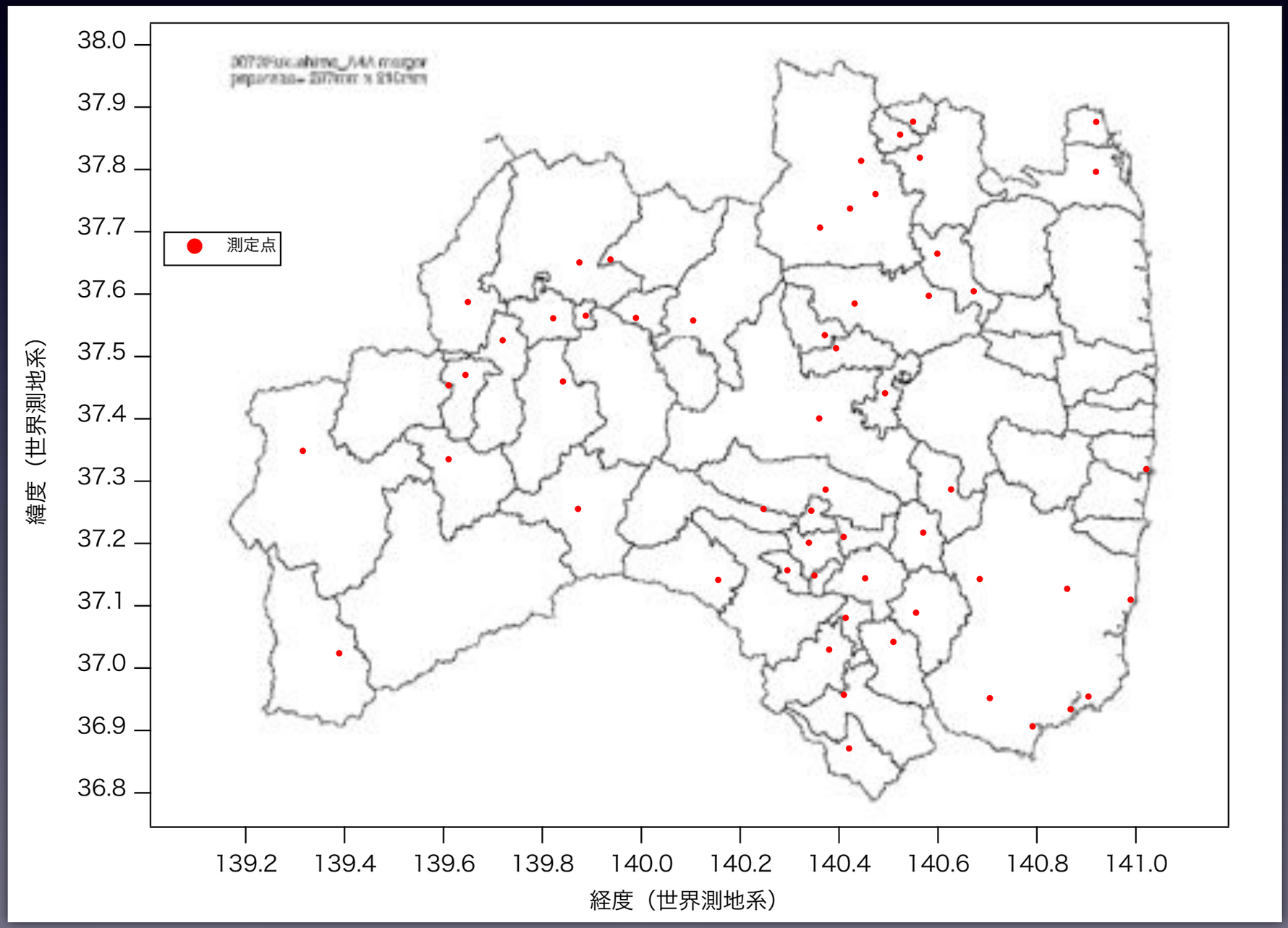


Data center
shut down

Contaminated
monitoring car

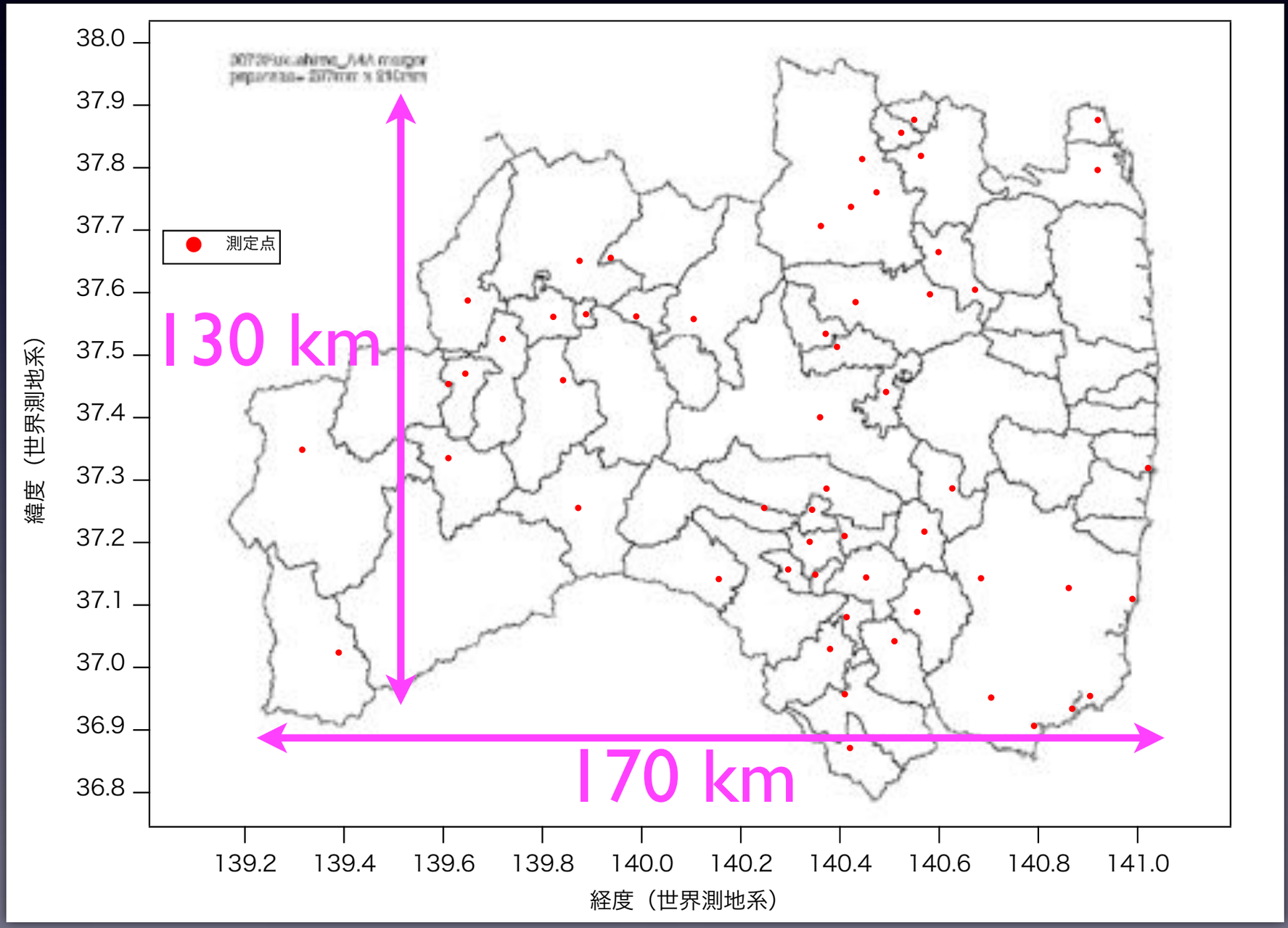
Monitoring by Hand

Twice a day, throughout Fukushima prefecture



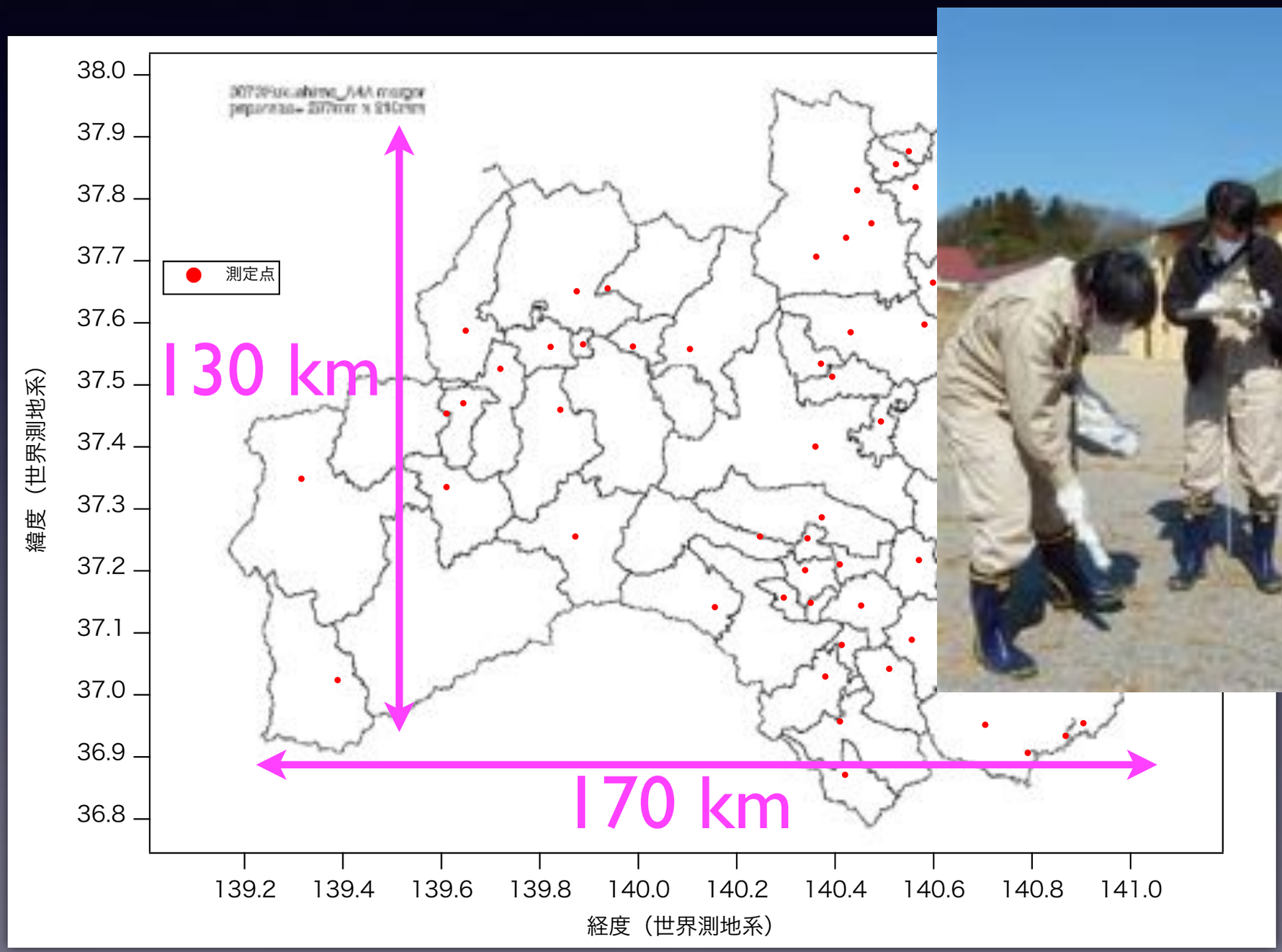
Monitoring by Hand

Twice a day, throughout Fukushima prefecture



Monitoring by Hand

Twice a day, throughout Fukushima prefecture



KURAMA

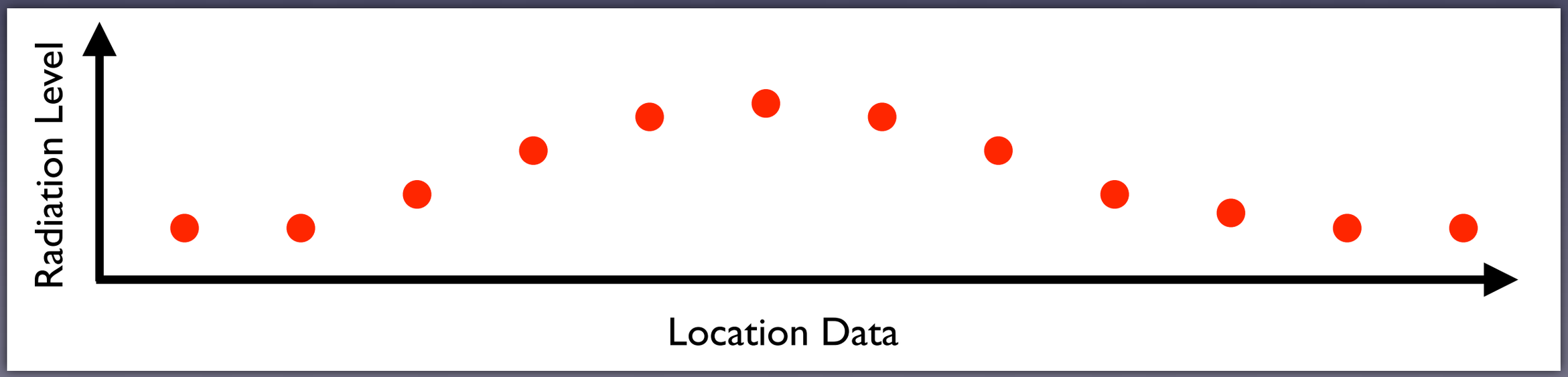
(Kyoto Univ. RAdiation MApping System)

Carborne Survey

Radiation measurement with location data from a vehicle

Carborne Survey

Radiation measurement with location data from a vehicle



KURAMA

A simple carborne survey system

System Configuration

Real time data collection over Dropbox

Monioring car

Monitoring car

Dropbox

Server/Client

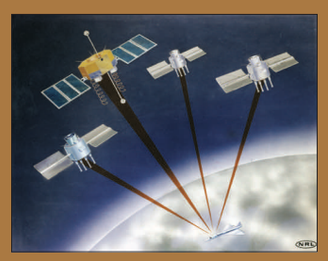
Server

Data processing/ Mapping

PC/Netbook

Radiation

Location data

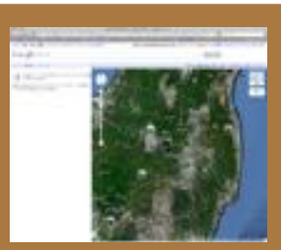


Radiation monitor

GPS

Client

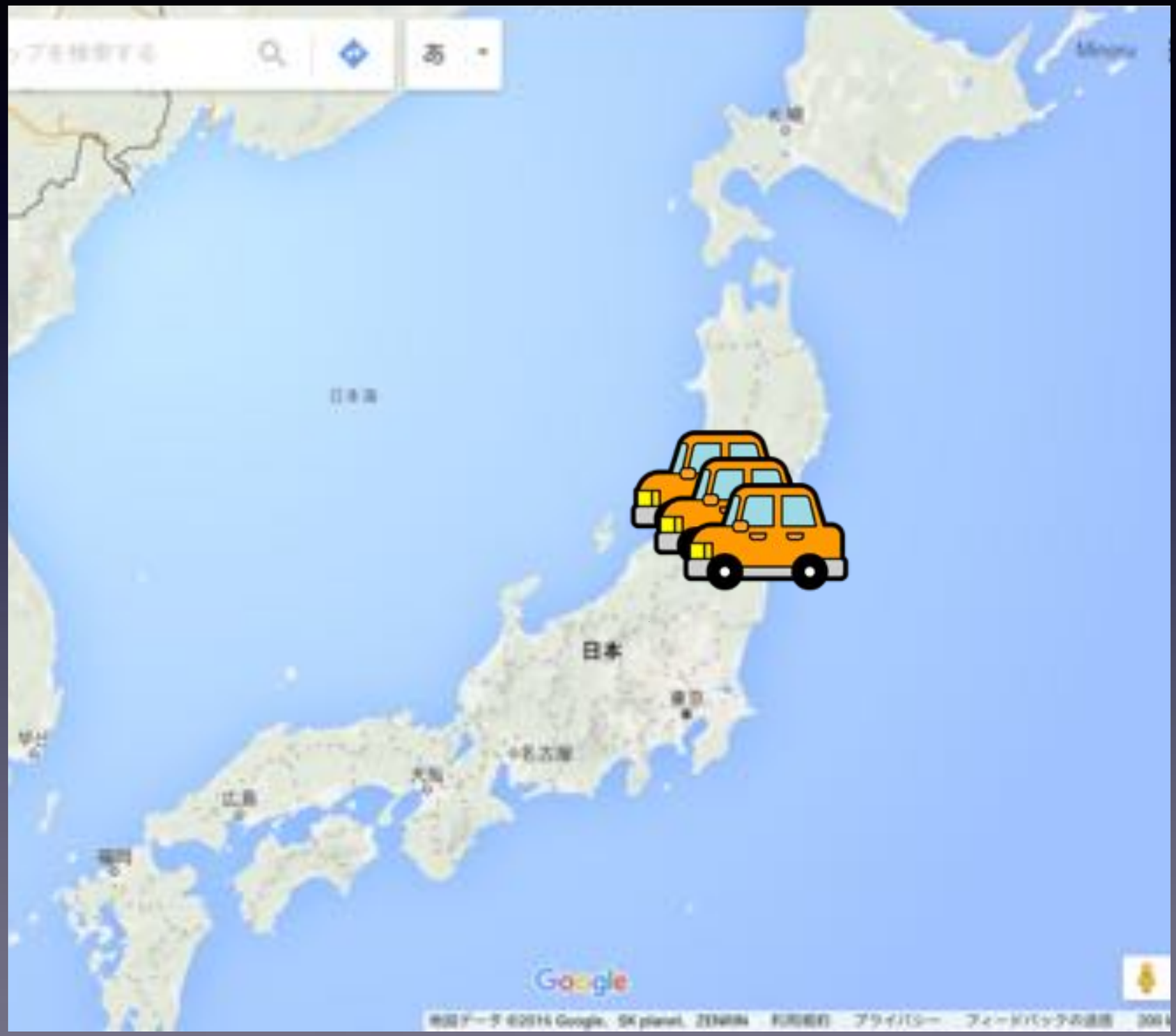
Client



GIS/Visualization

Sharing Data over Cloud

Sharing Data over Cloud



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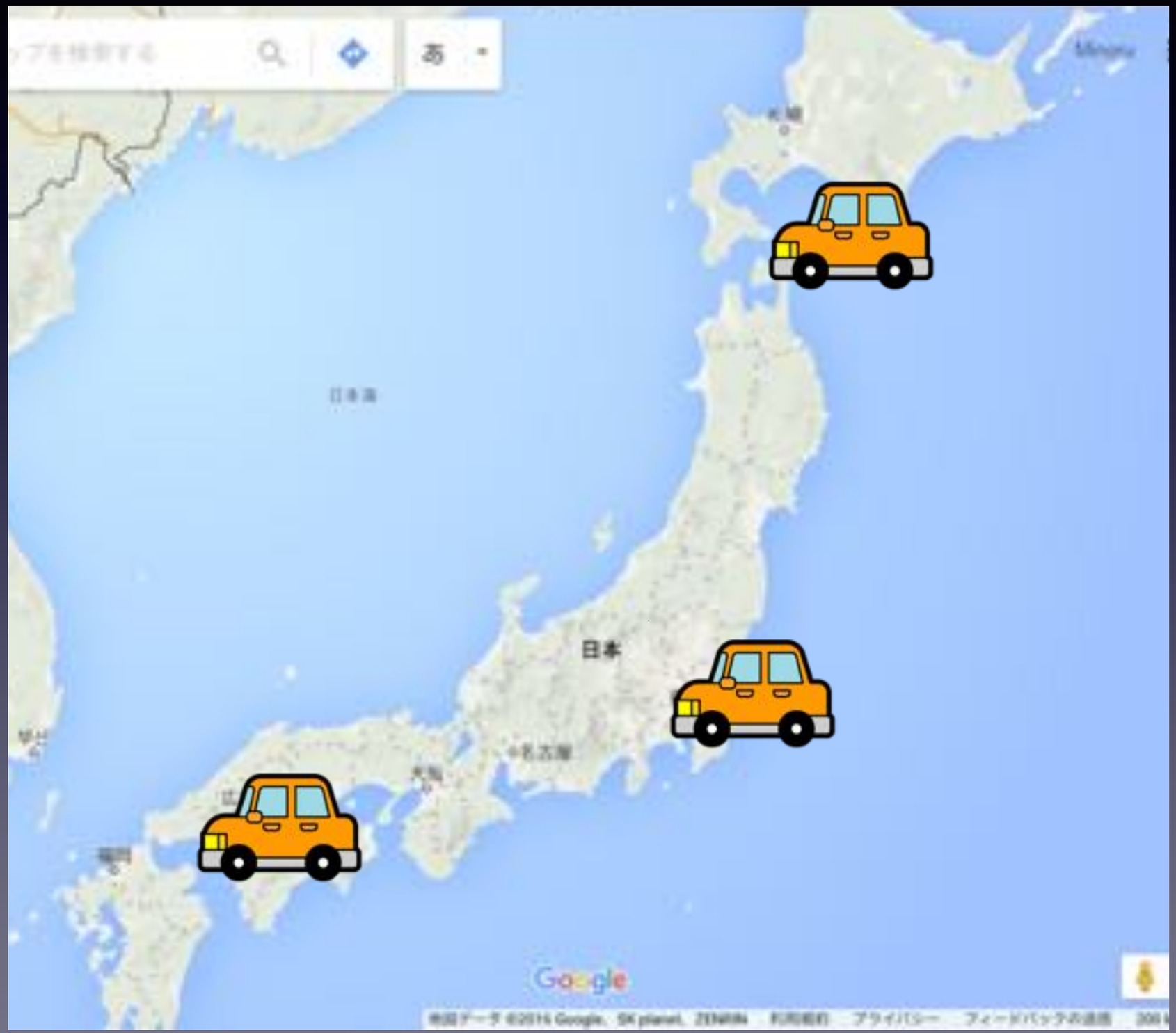

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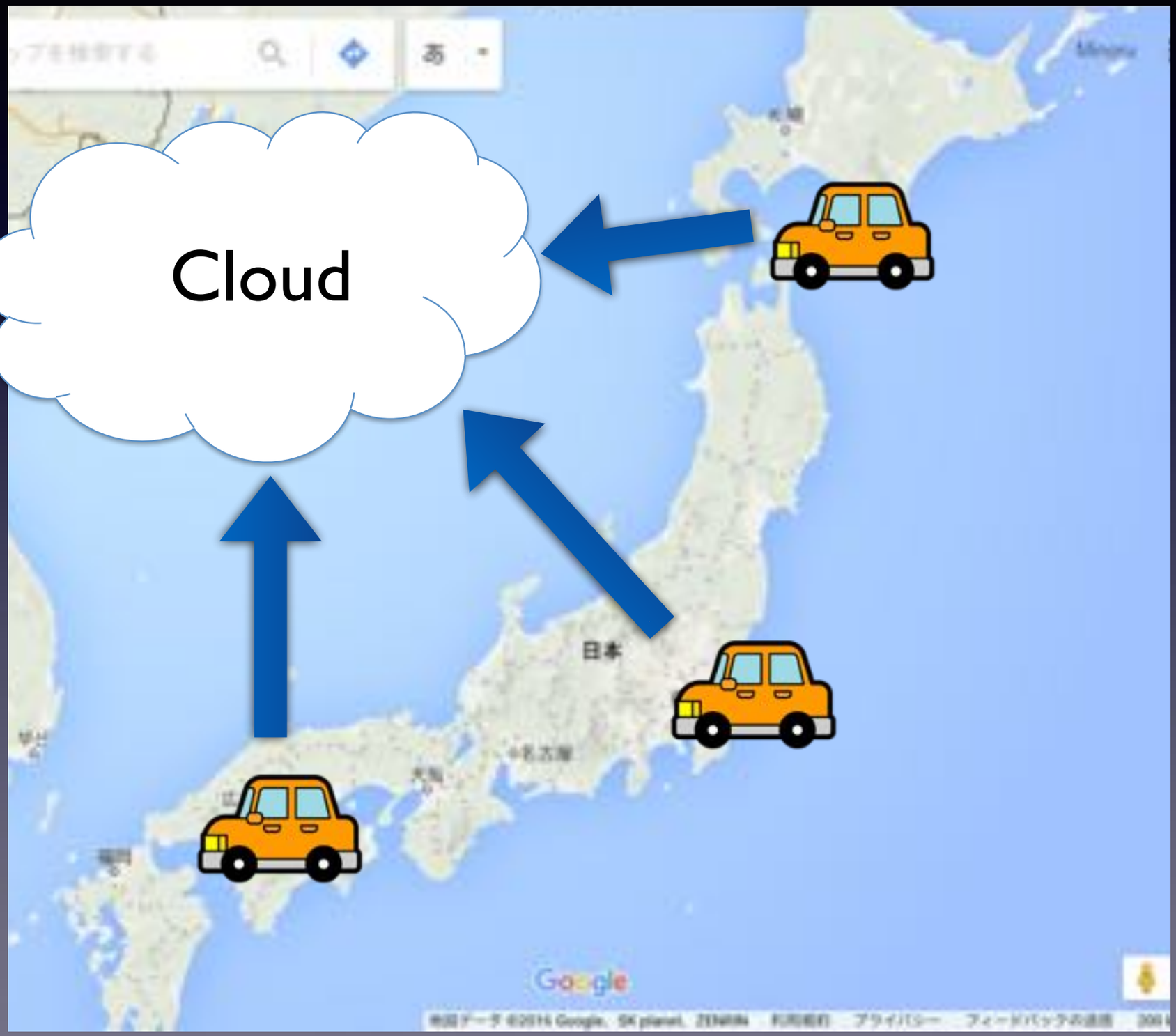

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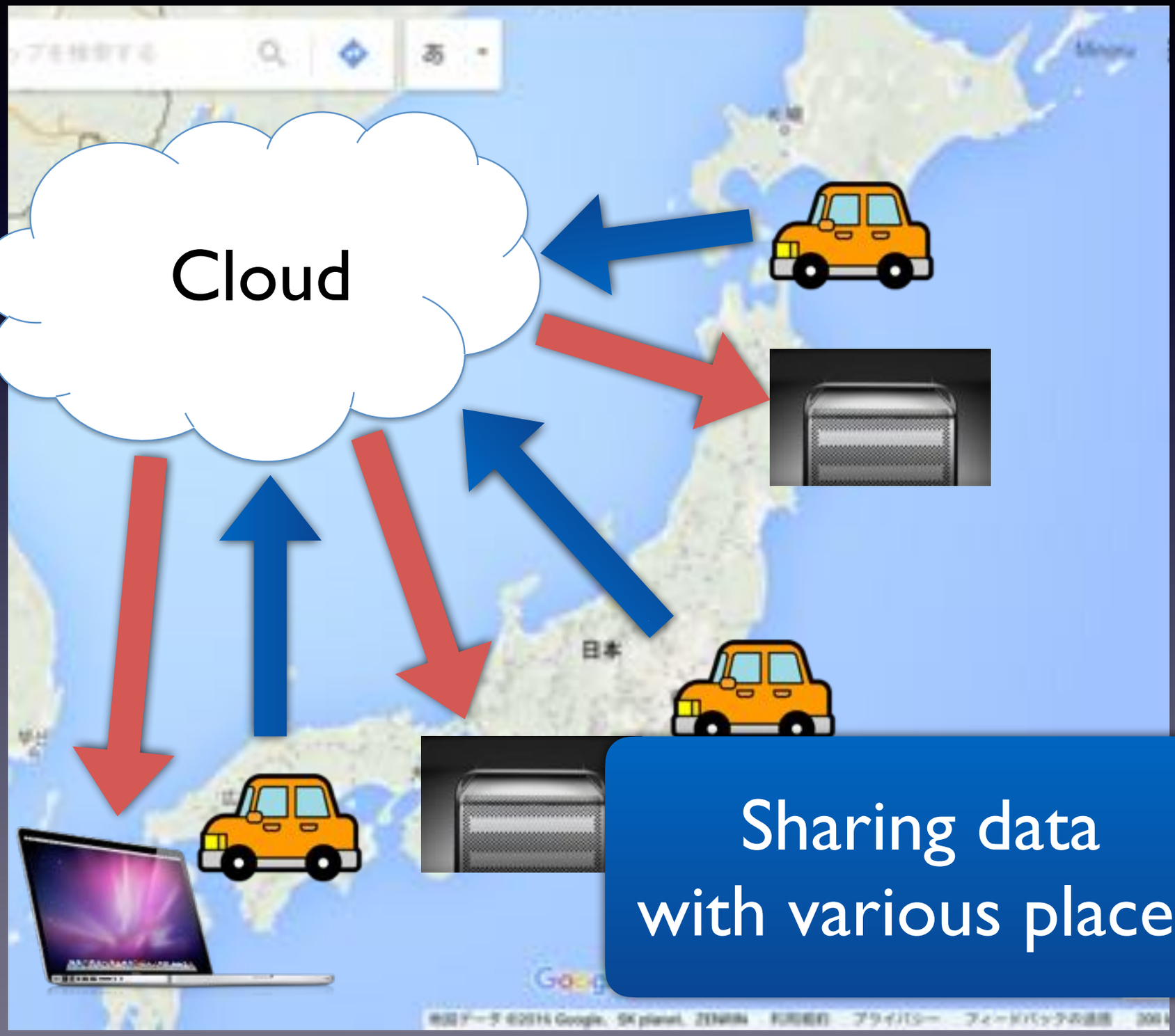

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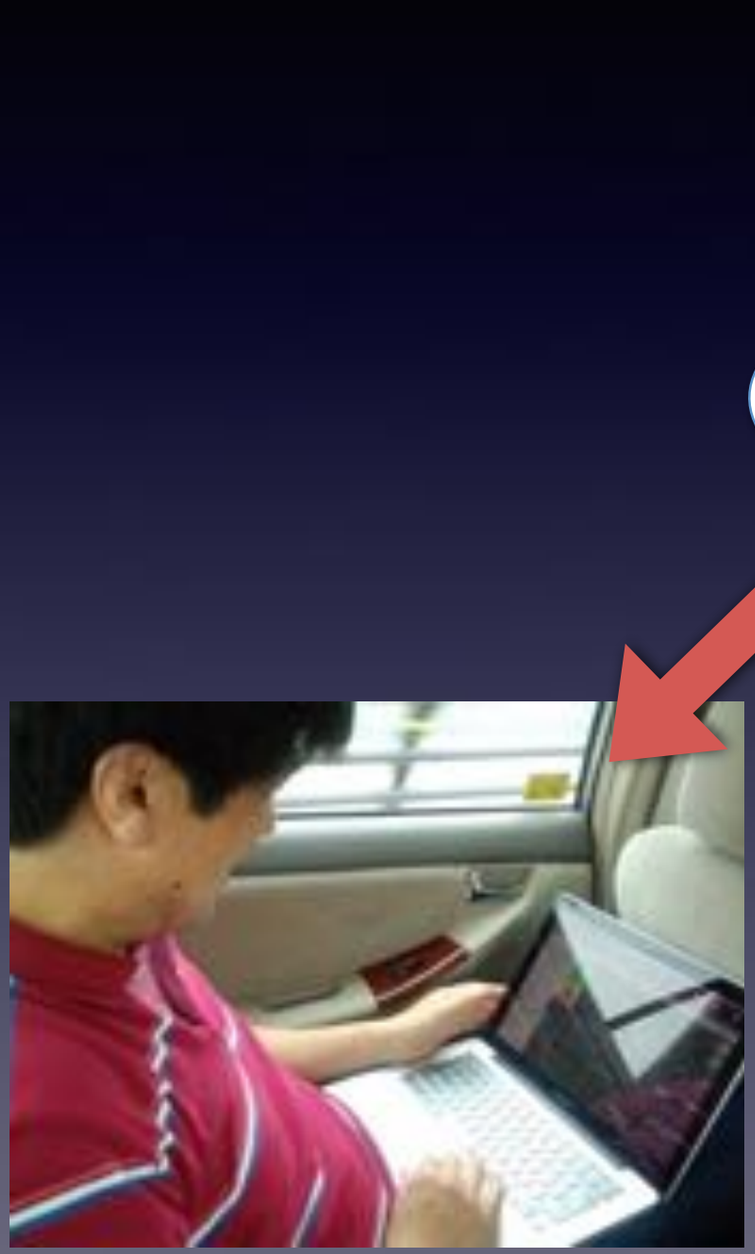
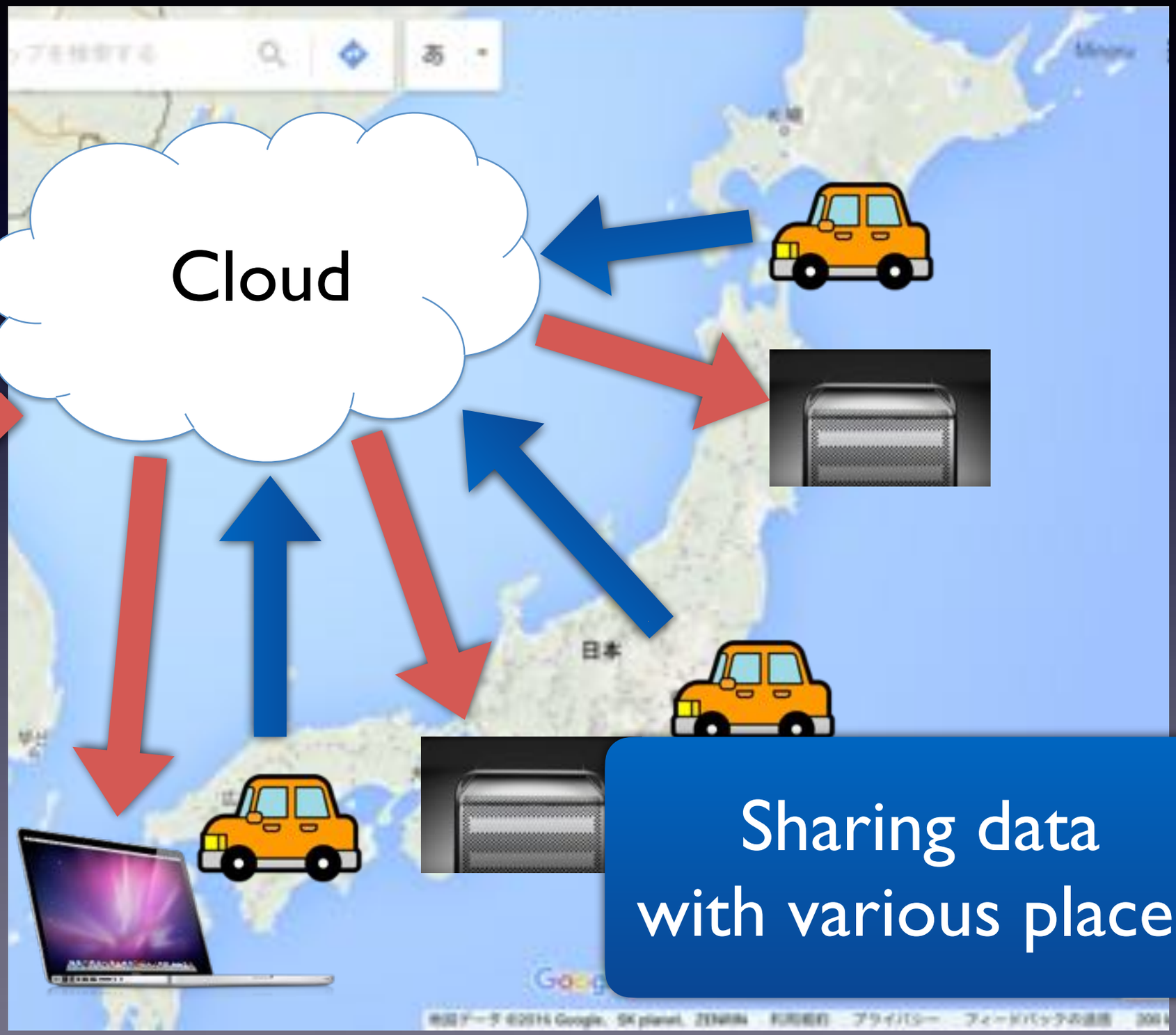
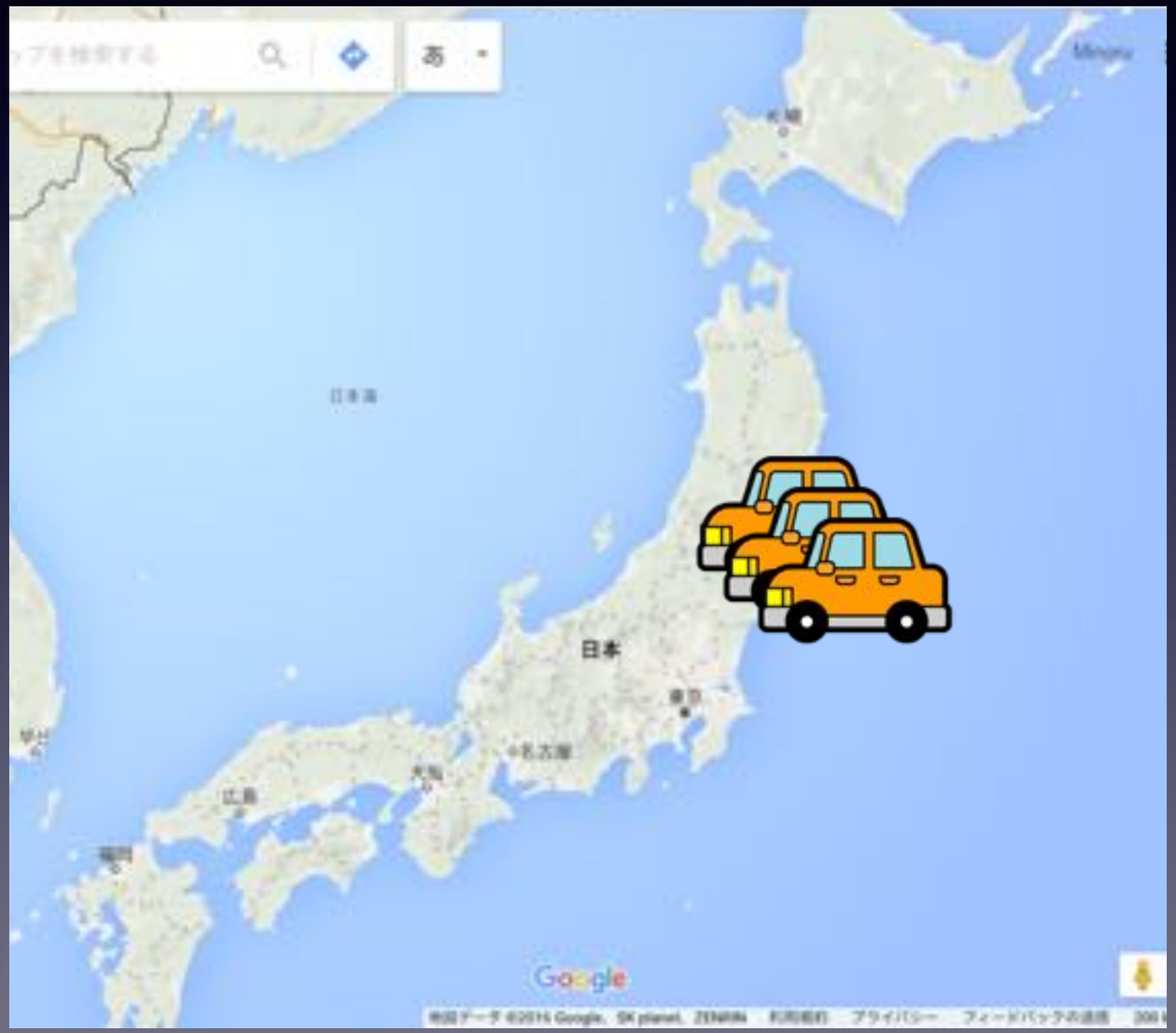




Other Systems

Relying on perfect manipulations by human



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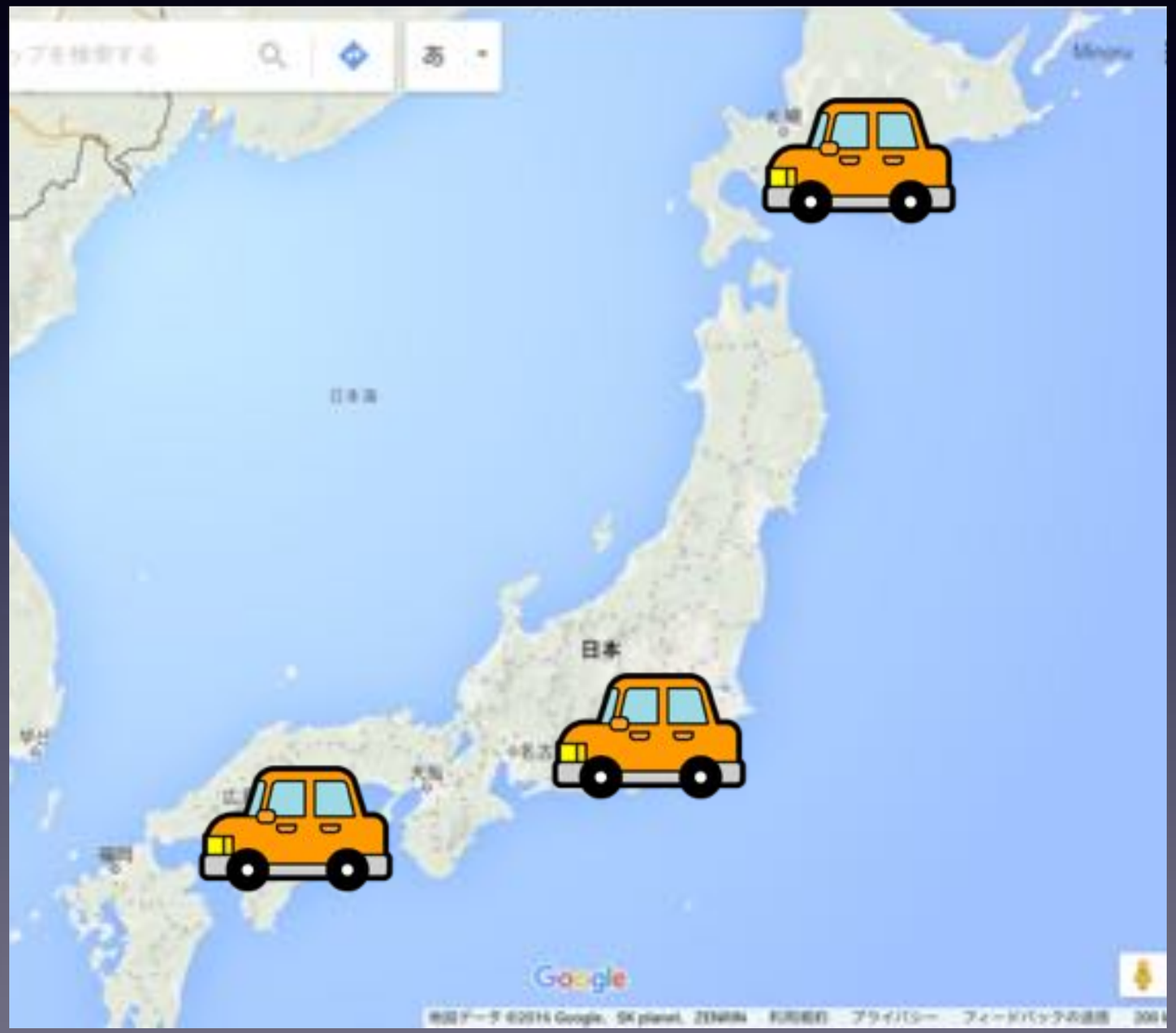

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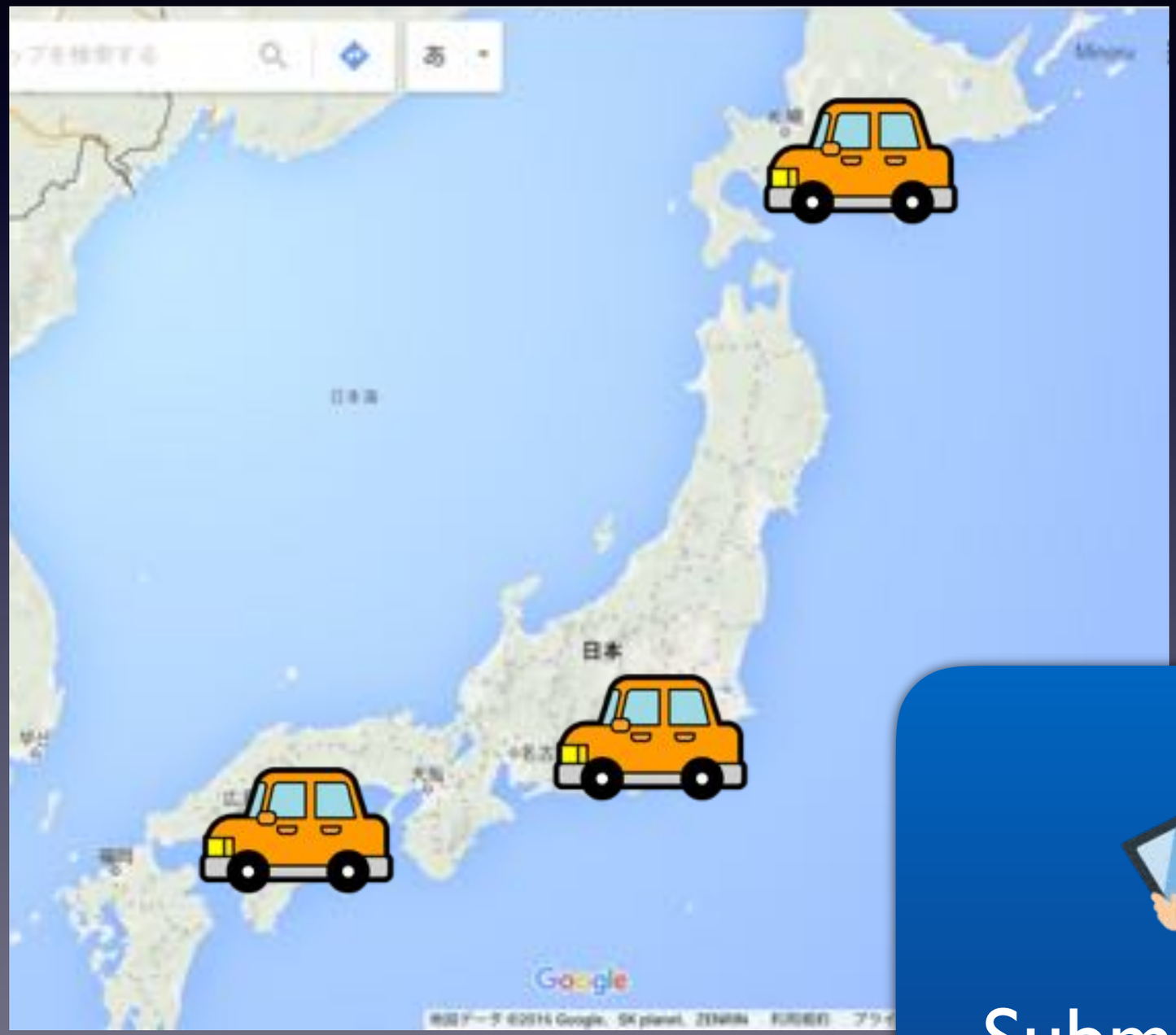
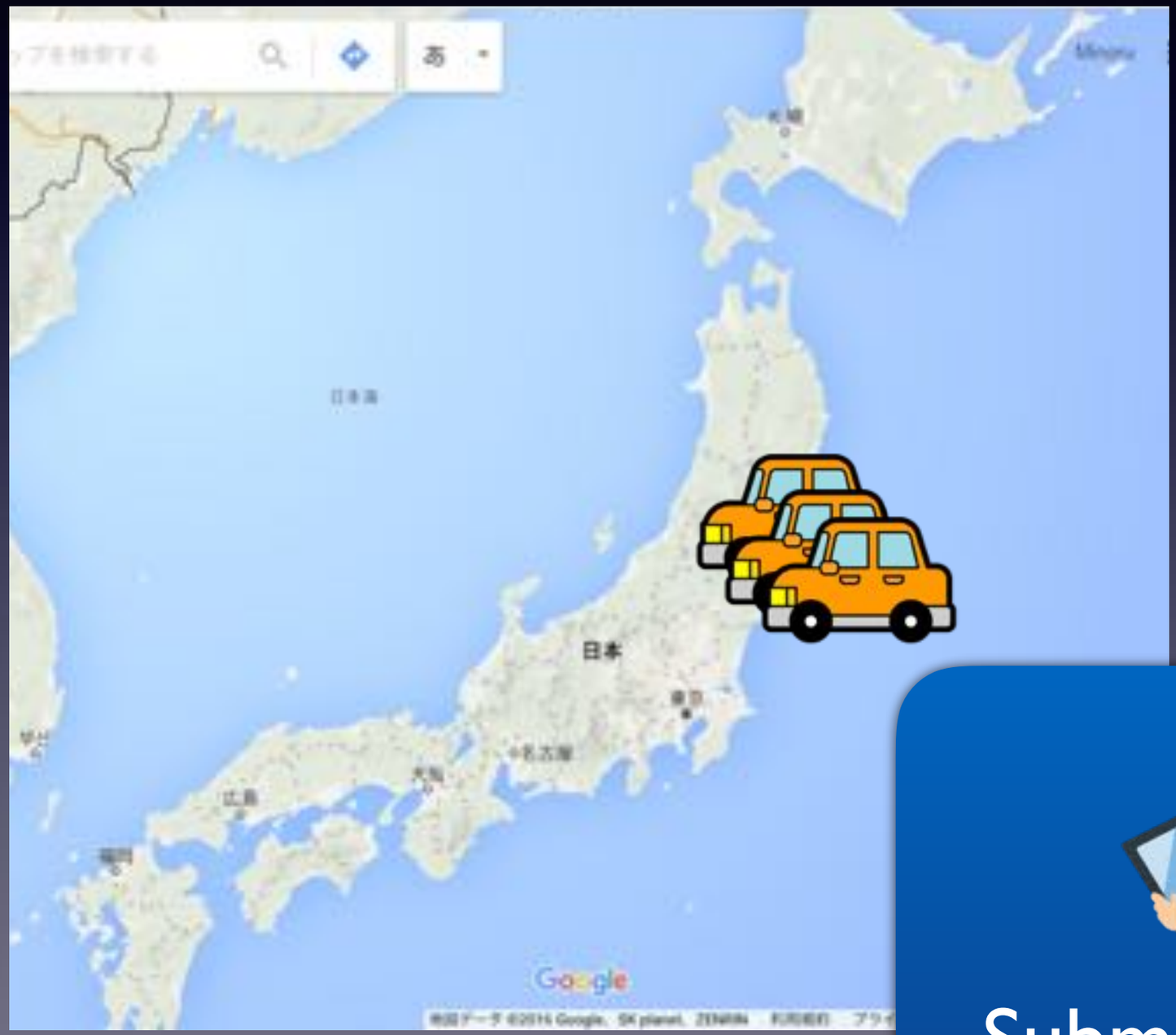


Submit by hand

Other Systems

Relying on perfect manipulations by human



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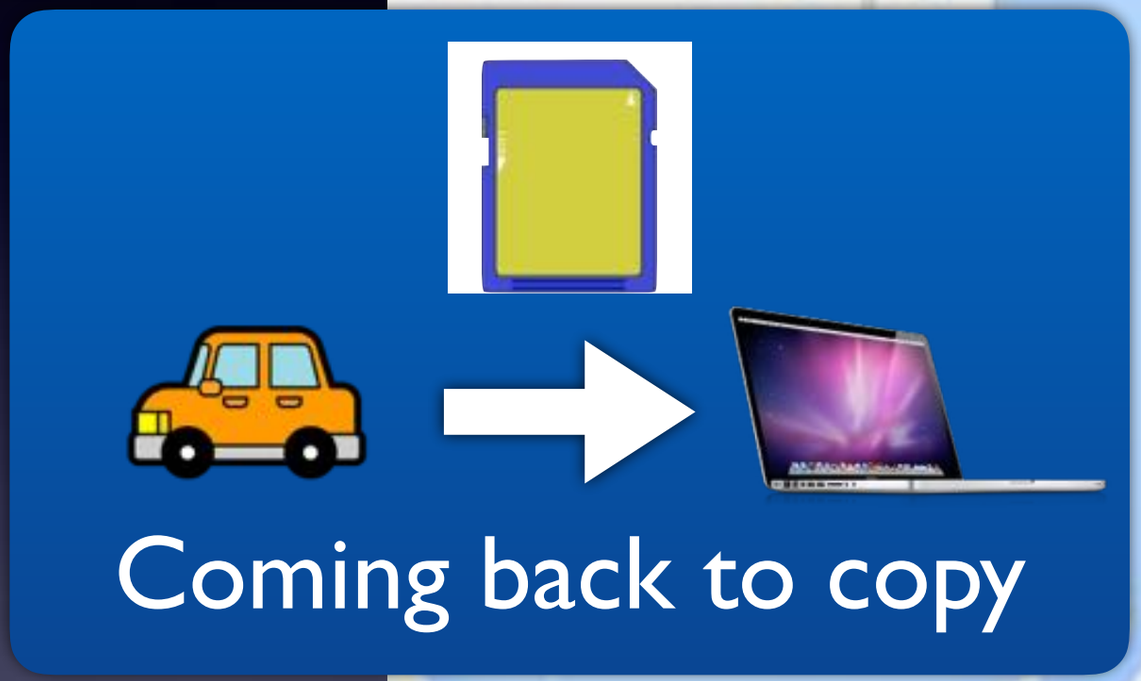


Coming back to copy

Submit by hand

Other Systems

Relying on perfect manipulations by human

Comin

- Human errors
- Free ride on efforts

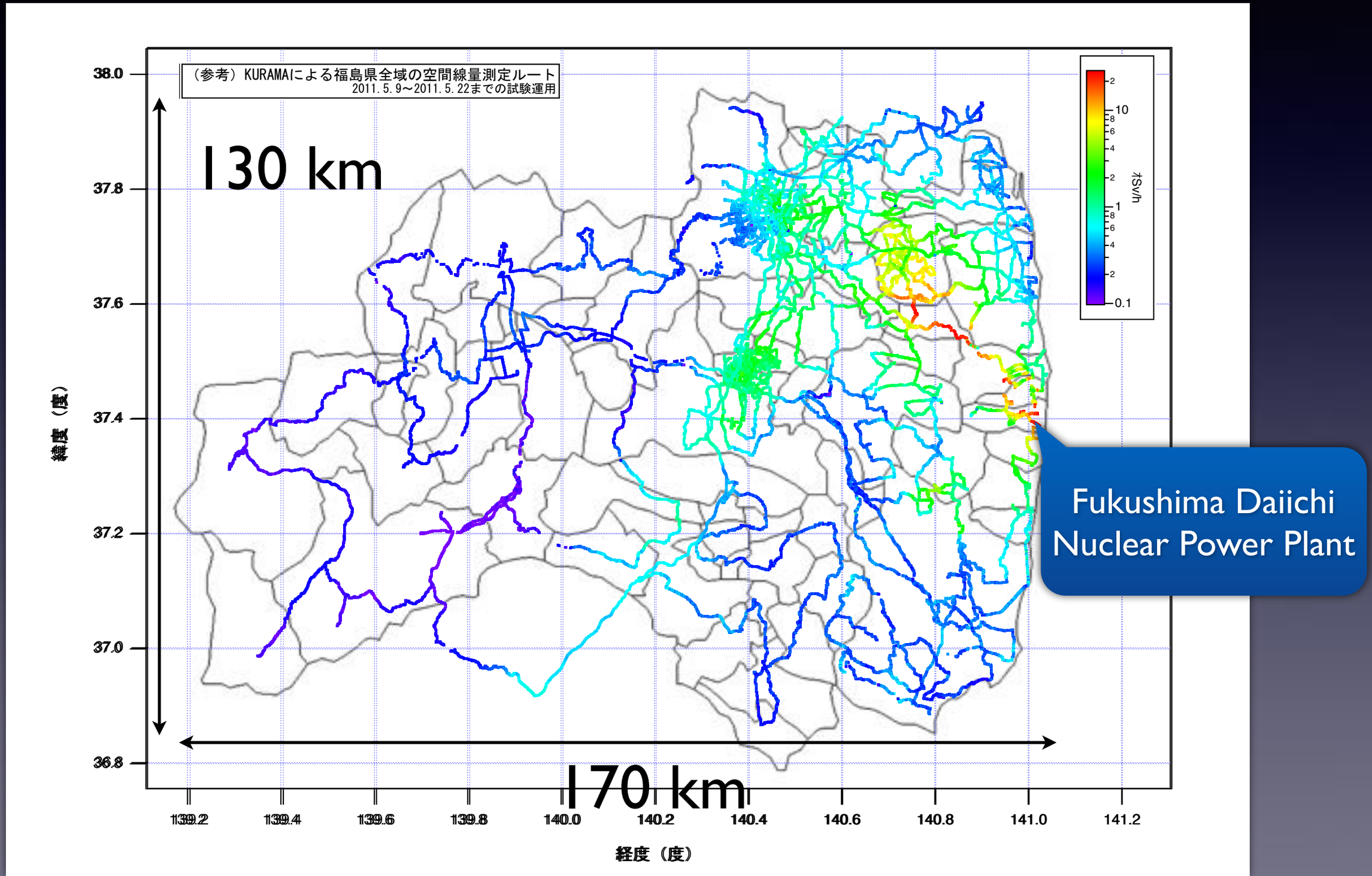
Submit by hand

Field Test in Fukushima, May 2011

Driving around 20,000 km for two weeks

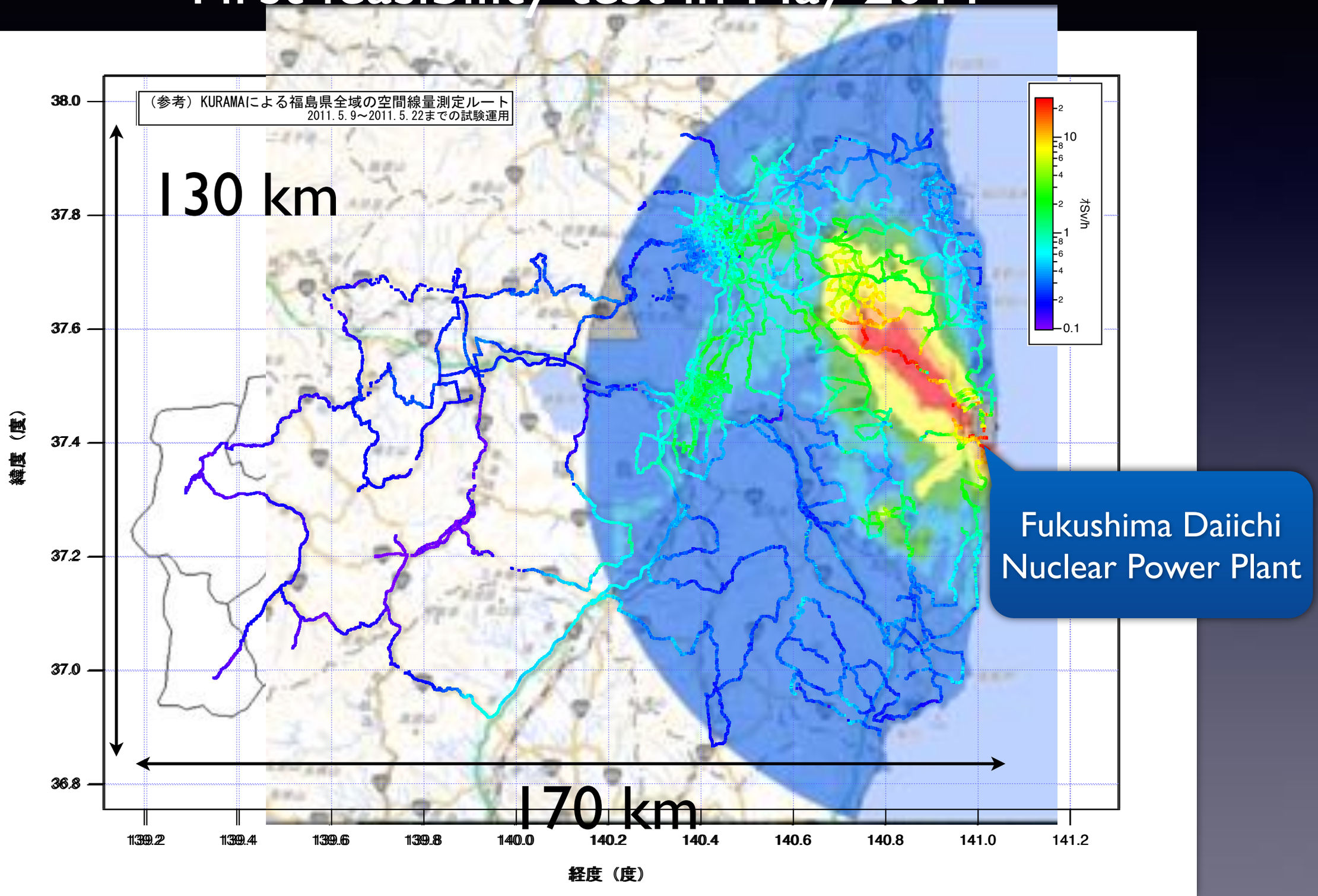
Result

First feasibility test in May 2011



Result

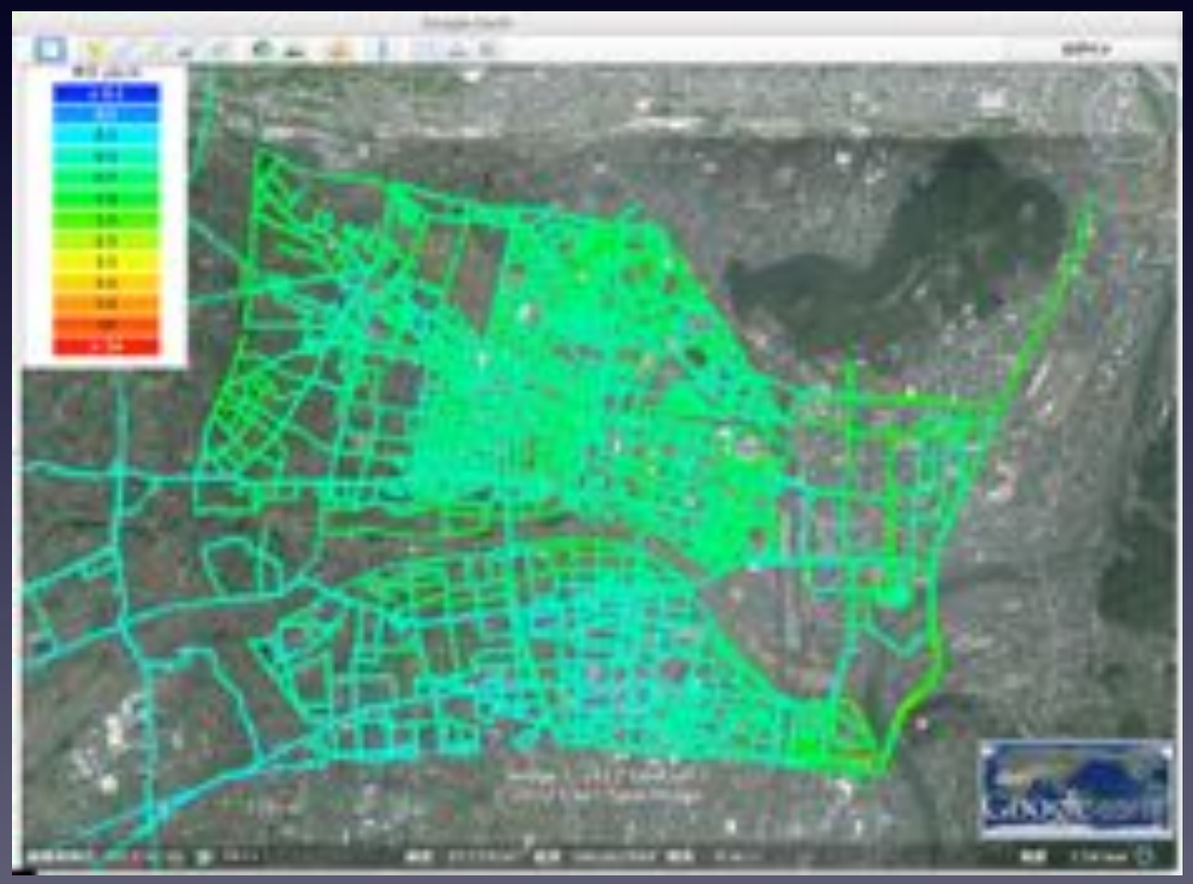
First feasibility test in May 2011



Outcome

Fukushima prefectural government

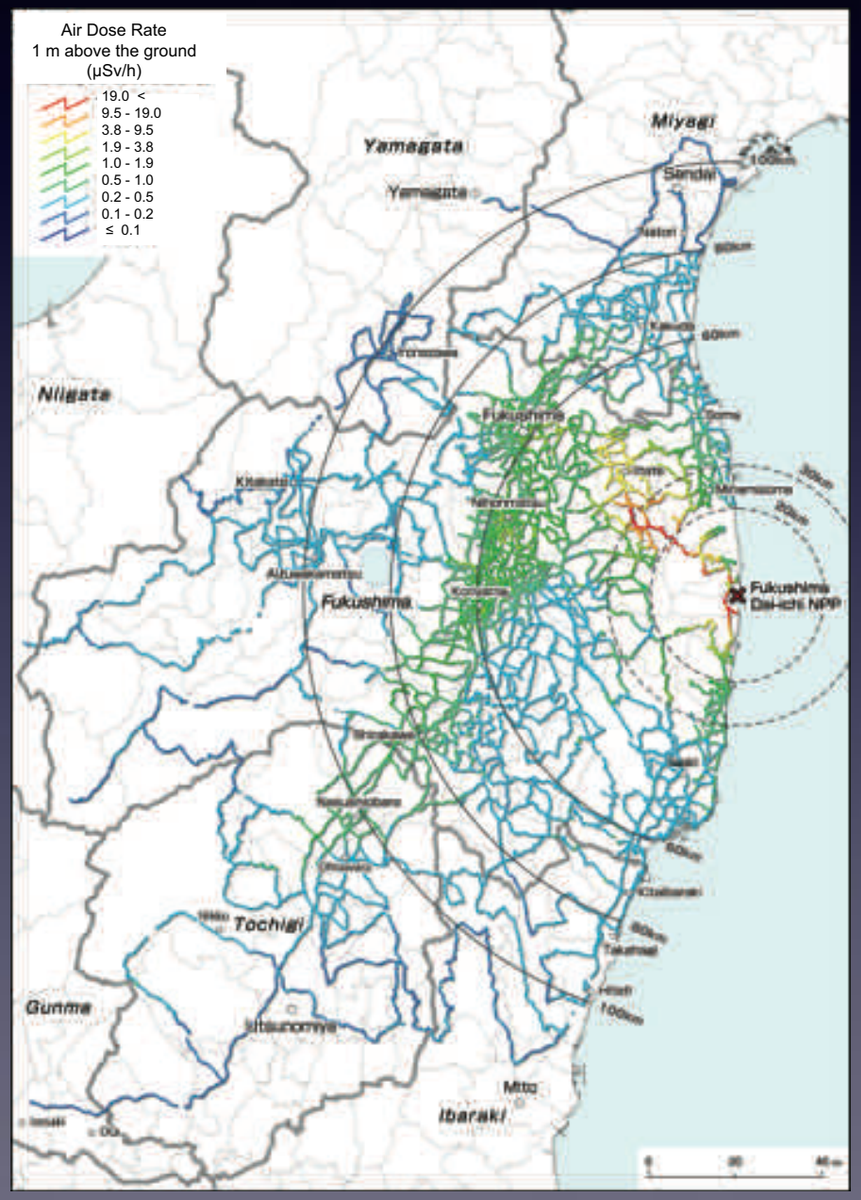
(Sep. 2011)



Every possible road in residential areas in Fukushima

Japanese government

(June 2011)



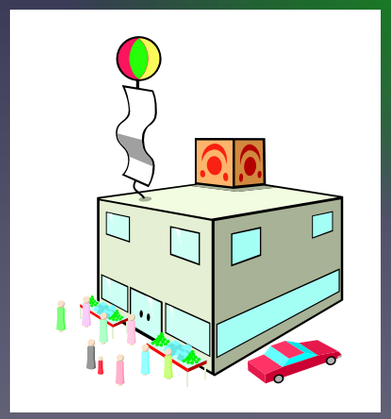
Beyond Fukushima prefecture

KURAMA-II

Disadvantage in KURAMA

Operators for setup, start, stop etc.

If KURAMA Becomes Small & Autonomous…



Residential area

Continuous monitoring in residential areas by buses, bikes etc.

In-vehicle Configuration

Rugged hardware, autonomous operation, succession of KURAMA software

Hamamatsu
C12137 Series

NI-VISA
USB-RAW

NI CompactRIO 9076

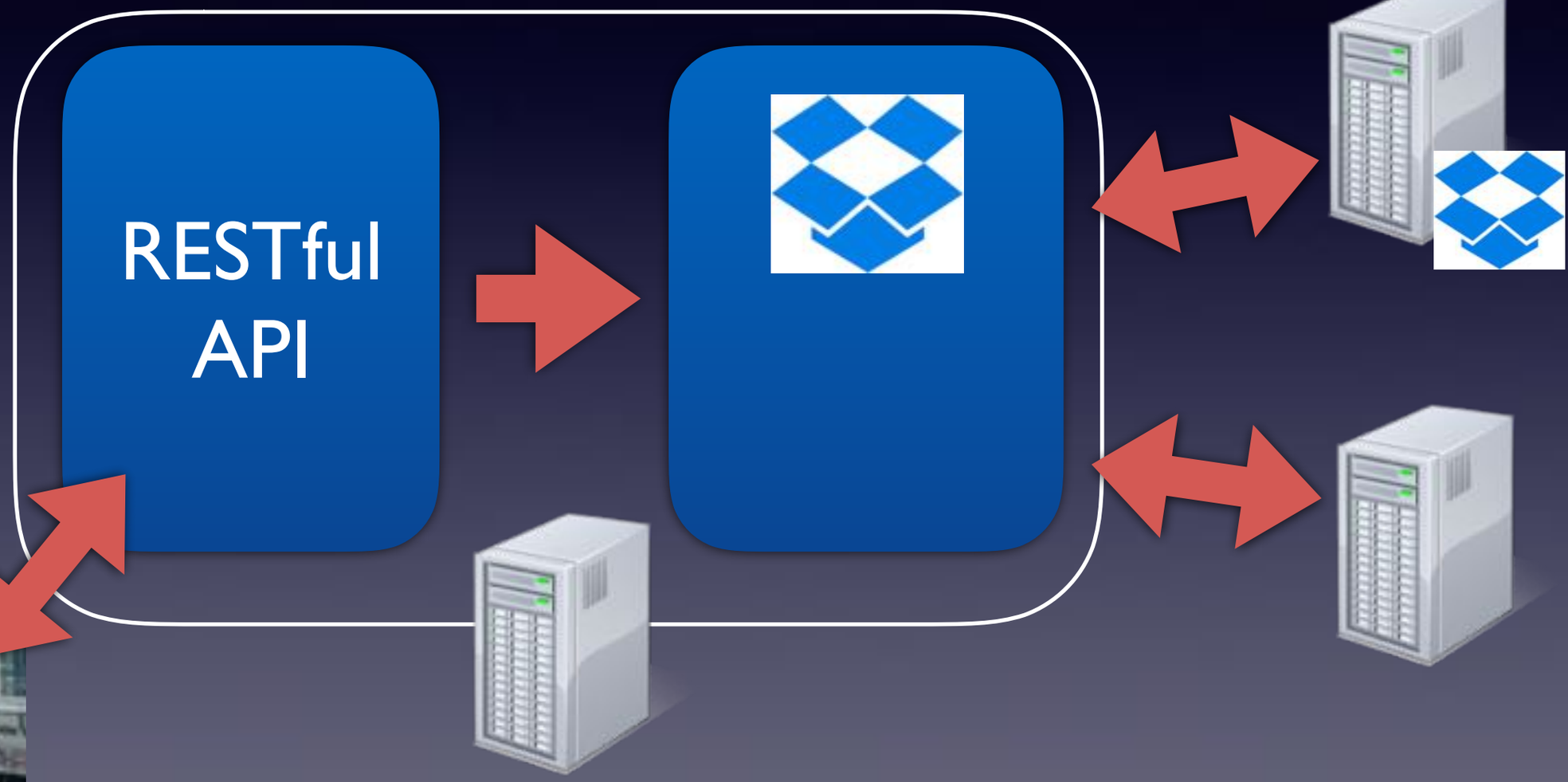
S.E.A.
3G/GPS module

CompactRIO

- LabVIEW ready
- Realtime OS
  (prev. VxWorks, now NI-Linux Realtime)
- Intel Processor (prev. PowerPC)
- FPGA
- Rugged system

Cloud for KURAMA-II

RESTful API + Dropbox or ownCloud



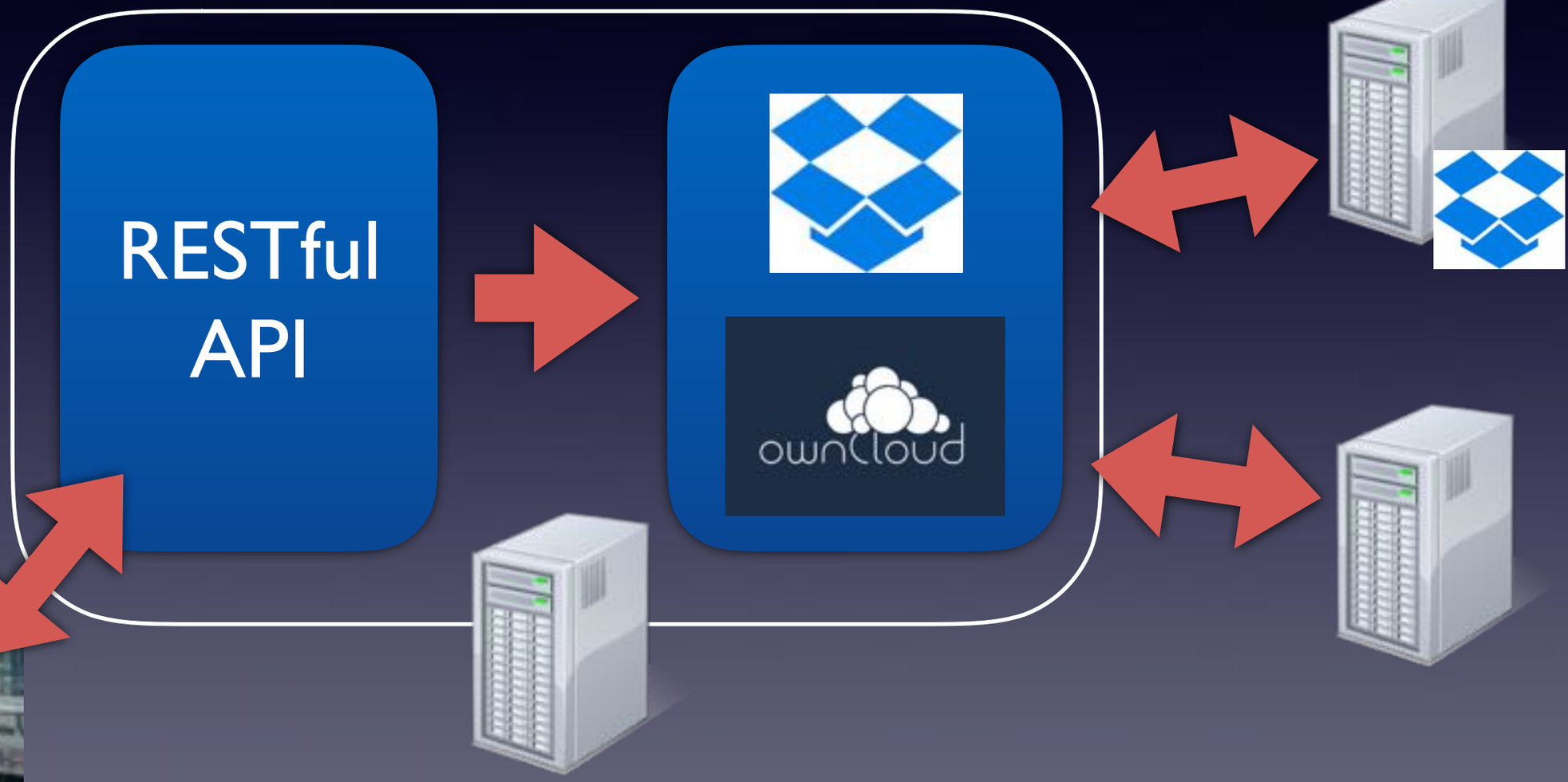
KURAMA-II

Server

Remote Server

Cloud for KURAMA-II

RESTful API + Dropbox or ownCloud



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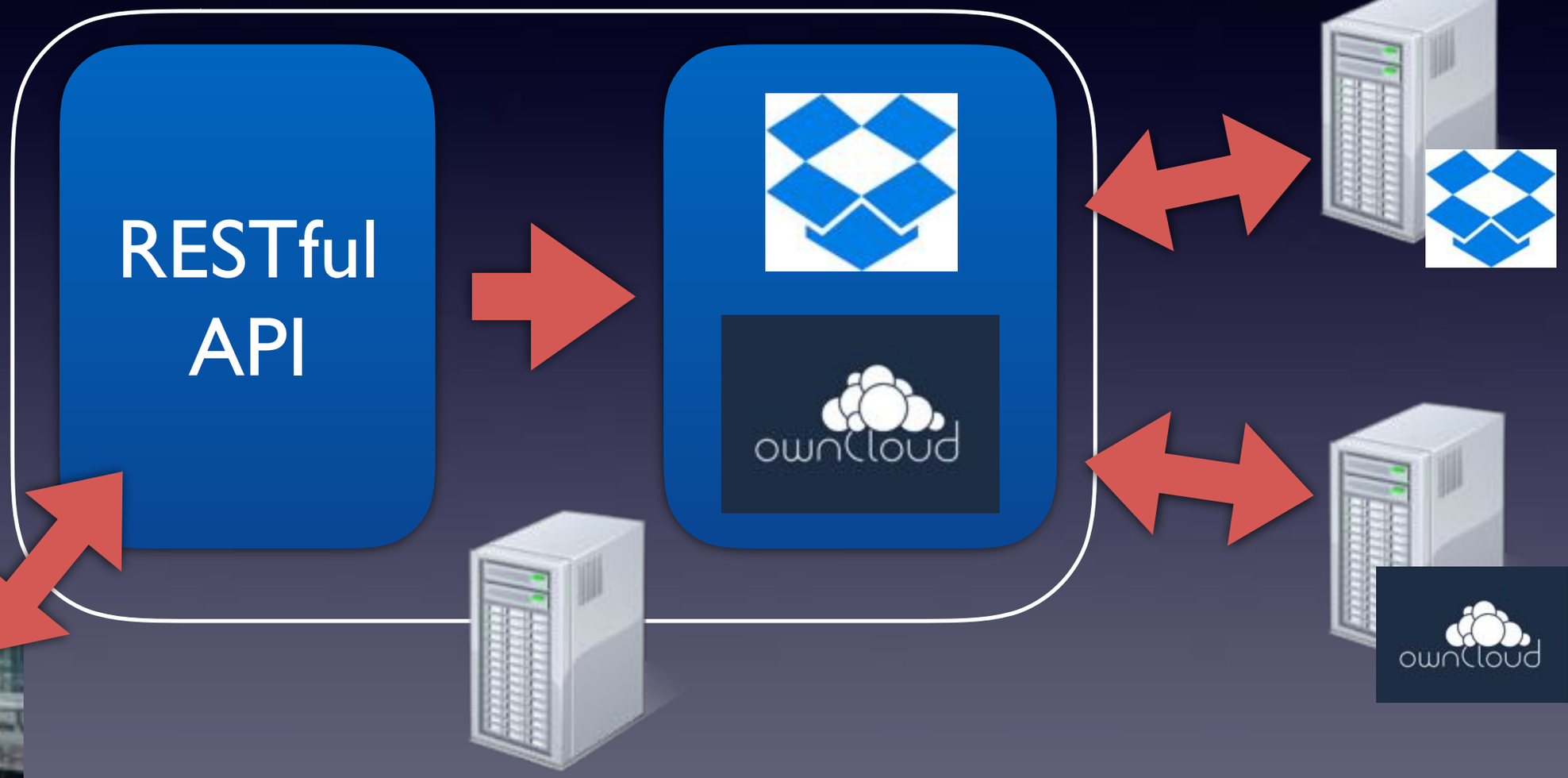


KURAMA-II

Server

Remote Server

File Transfer Protocol

RESTful with LabVIEW

cRIO

API server

Cloud

kurama_XX.txt

File Transfer Protocol

RESTful with LabVIEW

Small Text file
Containing
3 ~ 5 Points

D

API server

Cloud

kurama_XX.txt

File Transfer Protocol

RESTful with LabVIEW

cRIO

Transmission

API server

Cloud

kurama_XX.txt

File Transfer Protocol

RESTful with LabVIEW

cRIO

API server

Cloud

Transmission

Received List

kurama_XX.txt

File Transfer Protocol

RESTful with LabVIEW

cRIO

API server

Cloud

Transmission

Received List

Confirmed

kurama_XX.txt

File Transfer Protocol

RESTful with LabVIEW

cRIO

API server

Cloud

Transmission

Received List

Confirmed

Update

kurama_XX.txt

File Transfer Protocol

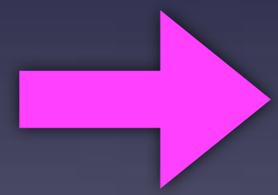
RESTful with LabVIEW

cRIO

API server

Cloud

Update



kurama_XX.txt

File Transfer Protocol

RESTful with LabVIEW

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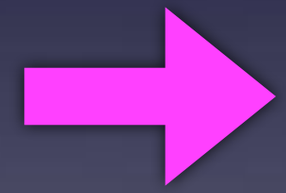


Cloud

kurama_XX.txt

File Transfer Protocol

RESTful with LabVIEW

cRIO

Transmission

API server

Update

Cloud

kurama_XX.txt

File Transfer Protocol

RESTful with LabVIEW

cRIO

API server

Cloud

Transmission

Containing
100 Text Files

Update

kurama_XX.txt

File Transfer Protocol

RESTful with LabVIEW

cRIO

API server

Cloud

Transmission

Containing
100 Text Files

Update

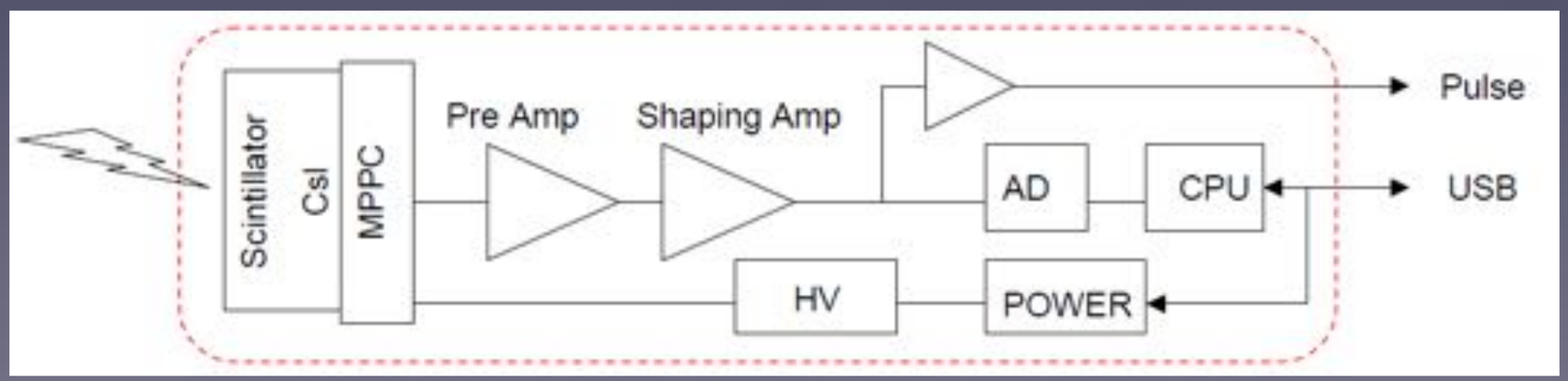
kurama_XX.txt

Hamamatsu C12137

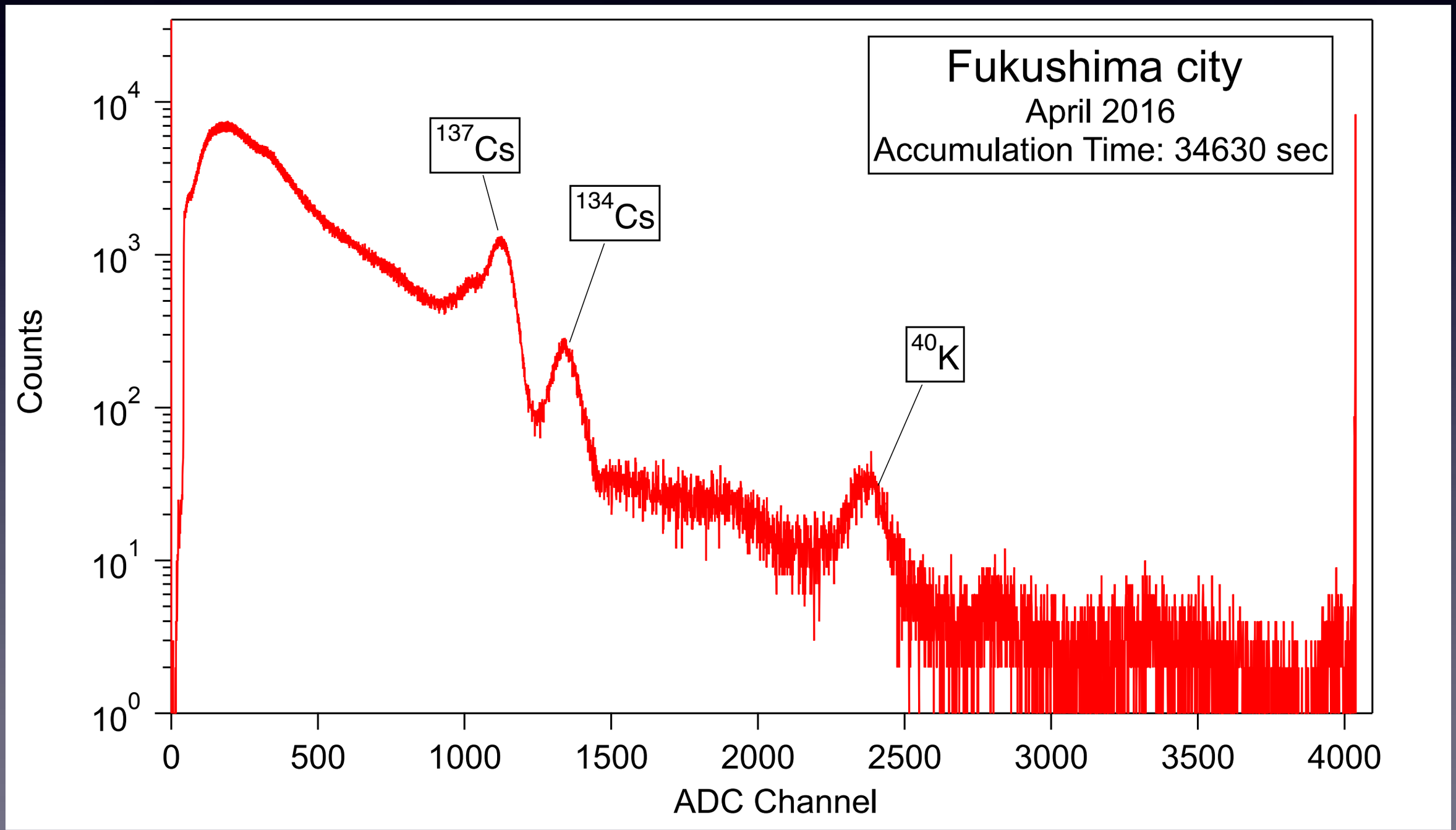
CsI detector with MPPC, operation by USB bus-power

CsI 3.4 cc
0.01~100 μSv/h

CsI 36 cc
0.001~10 μSv/h



Pulse Height Spectrum by KURAMA-II

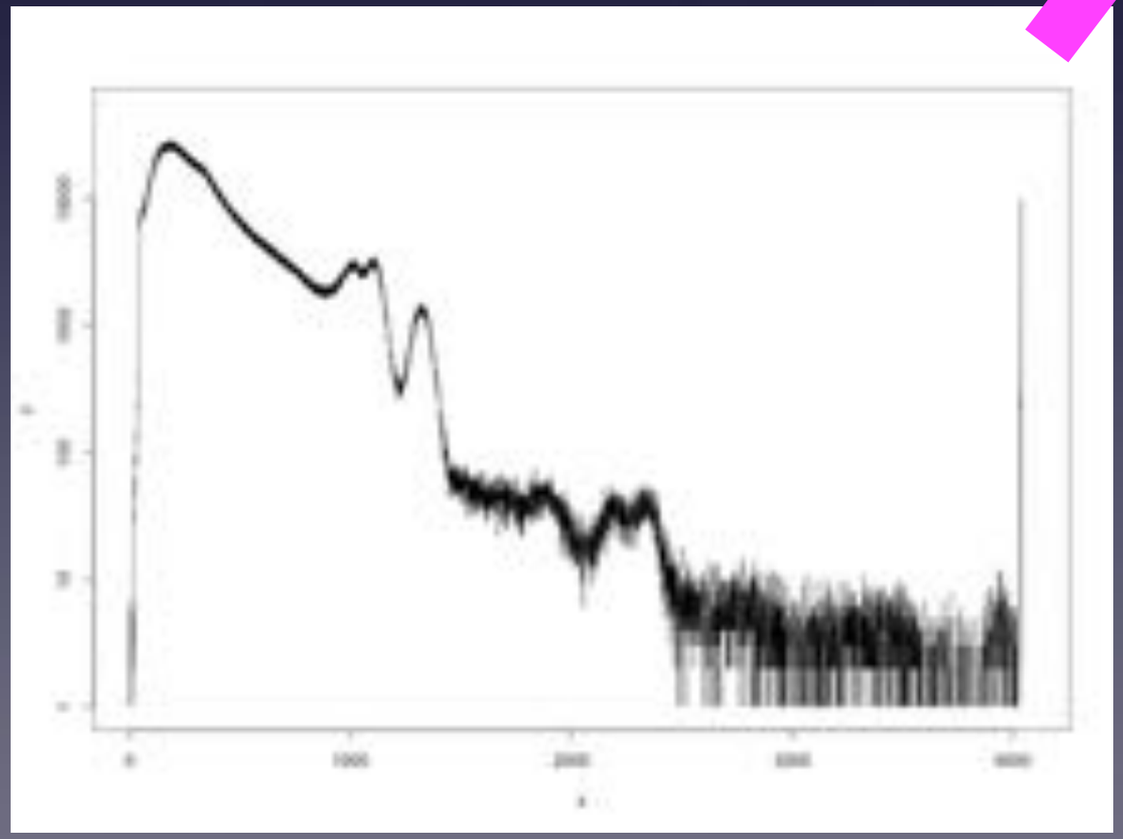


Air Dose Rate

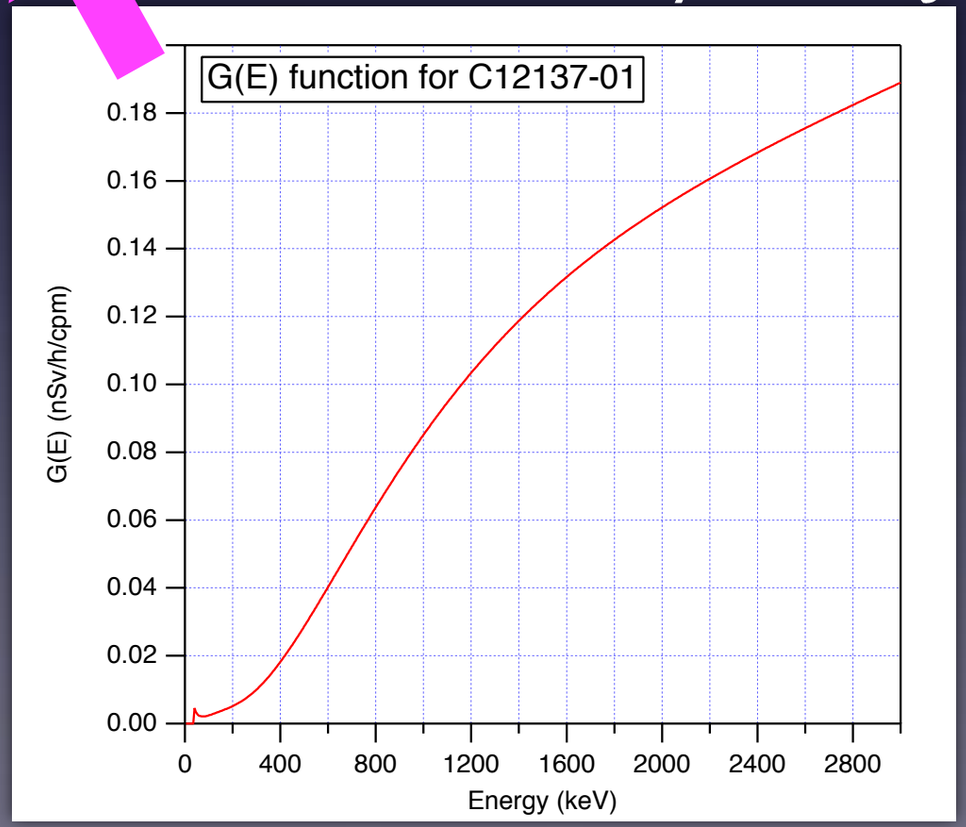
G(E) function: Energy response of the detector and tissue

$$D = \int_0^\infty N(\mathrm{E})G(\mathrm{E})d\mathrm{E}$$

Determined by Tsuda (JAEA)



Pulse height spectrum



G(E) function

Geiger-Muller Tubes

Only counting the number of incoming radiation

from LND website (http://www.lndinc.com/products/category/2/)

Is it OK to calibrate only with ^{137}Cs?

e.g. Calibration performed by Safecast

Energy Response of GM Pancake Detector

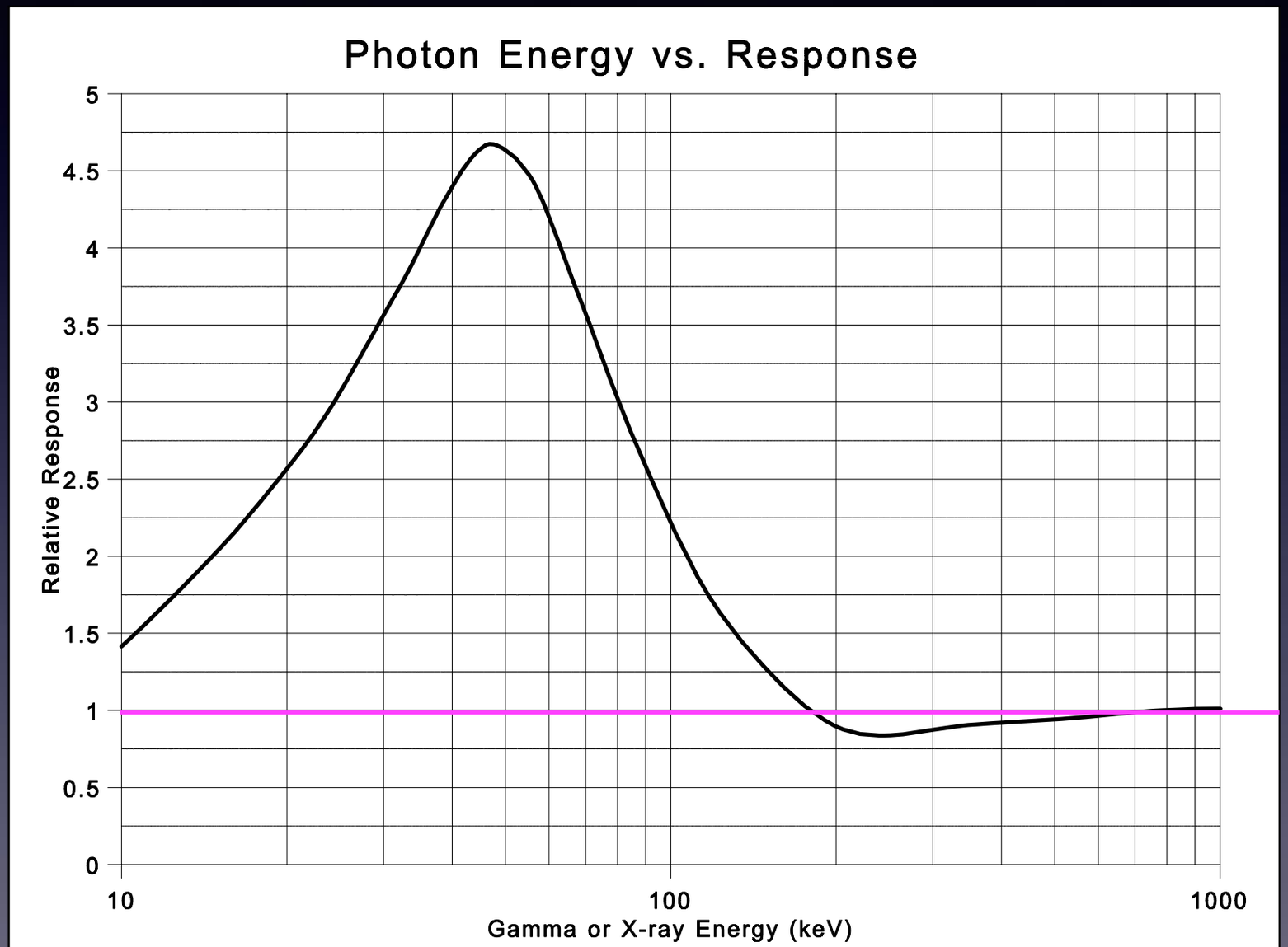


Figure 4. *Typical G-M pancake energy response curve.*

Paul R. Steinmeyer, RSO Magazine, 10 (2005) 7

Energy Response of GM Pancake Detector

Almost 5 times more sensitive

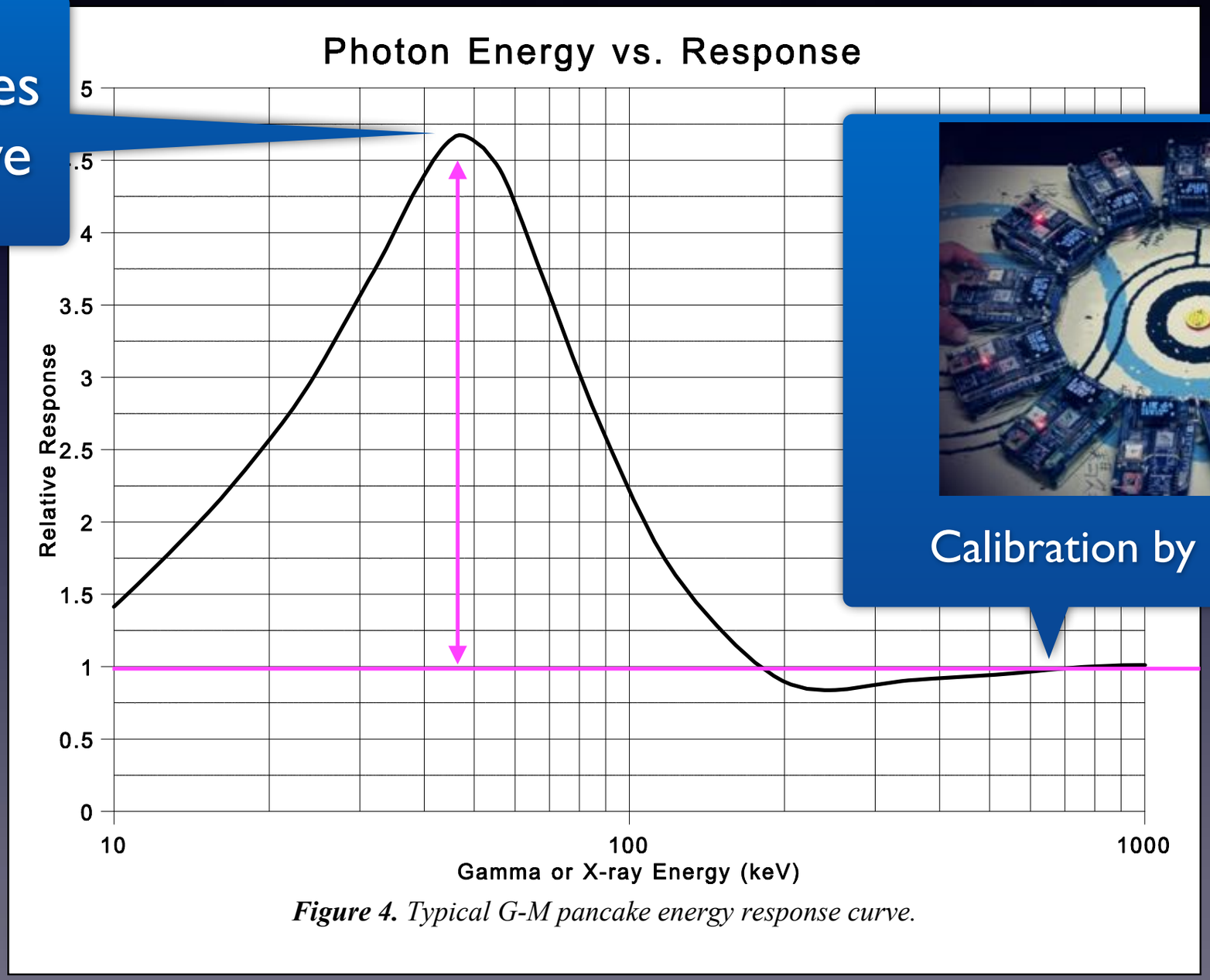
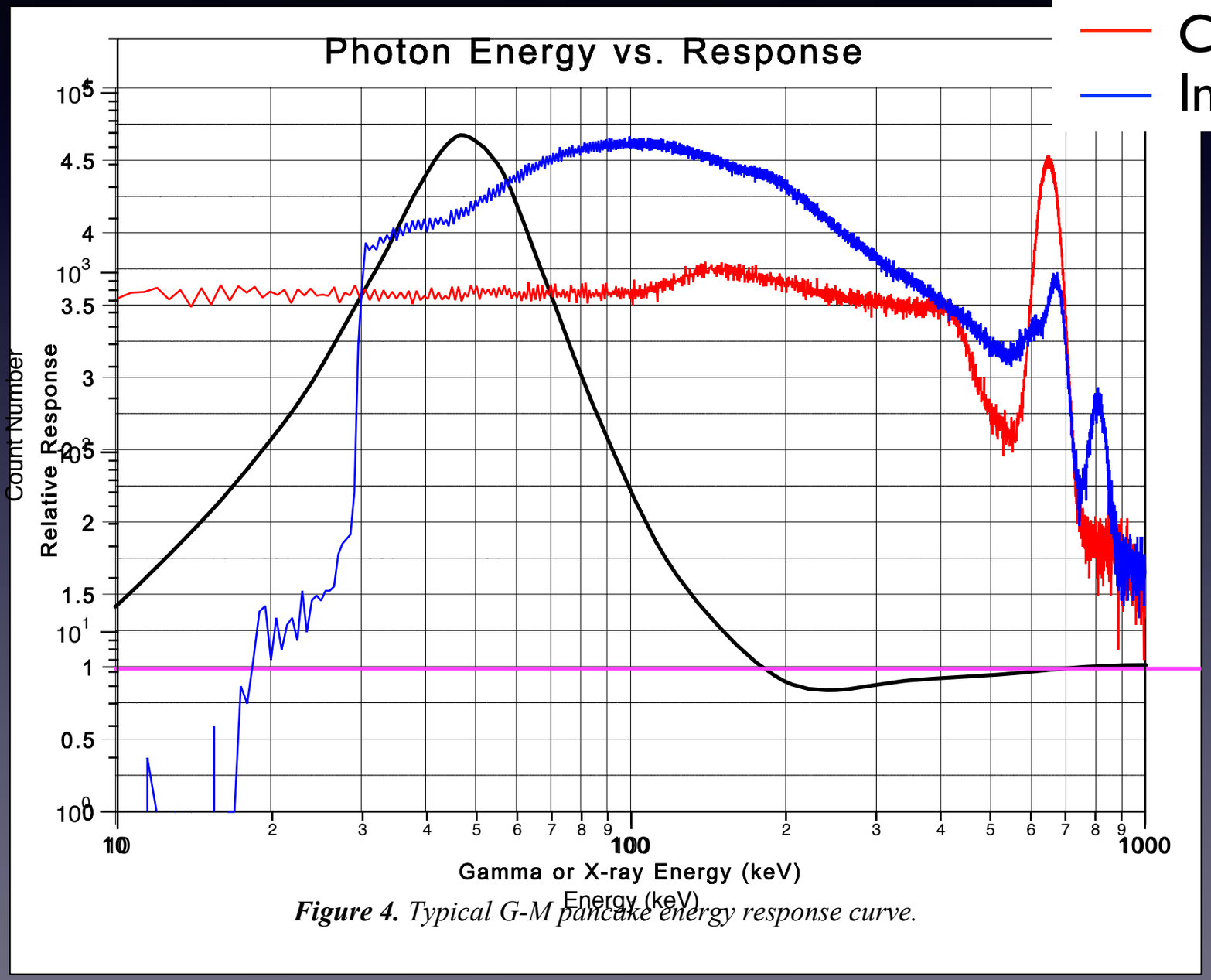


Figure 4. *Typical G-M pancake energy response curve.*

Calibration by ^{137}Cs Source

Paul R. Steinmeyer, RSO Magazine, 10 (2005) 7

Energy Response of GM Pancake Detector



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Energy Response of GM Pancake Detector

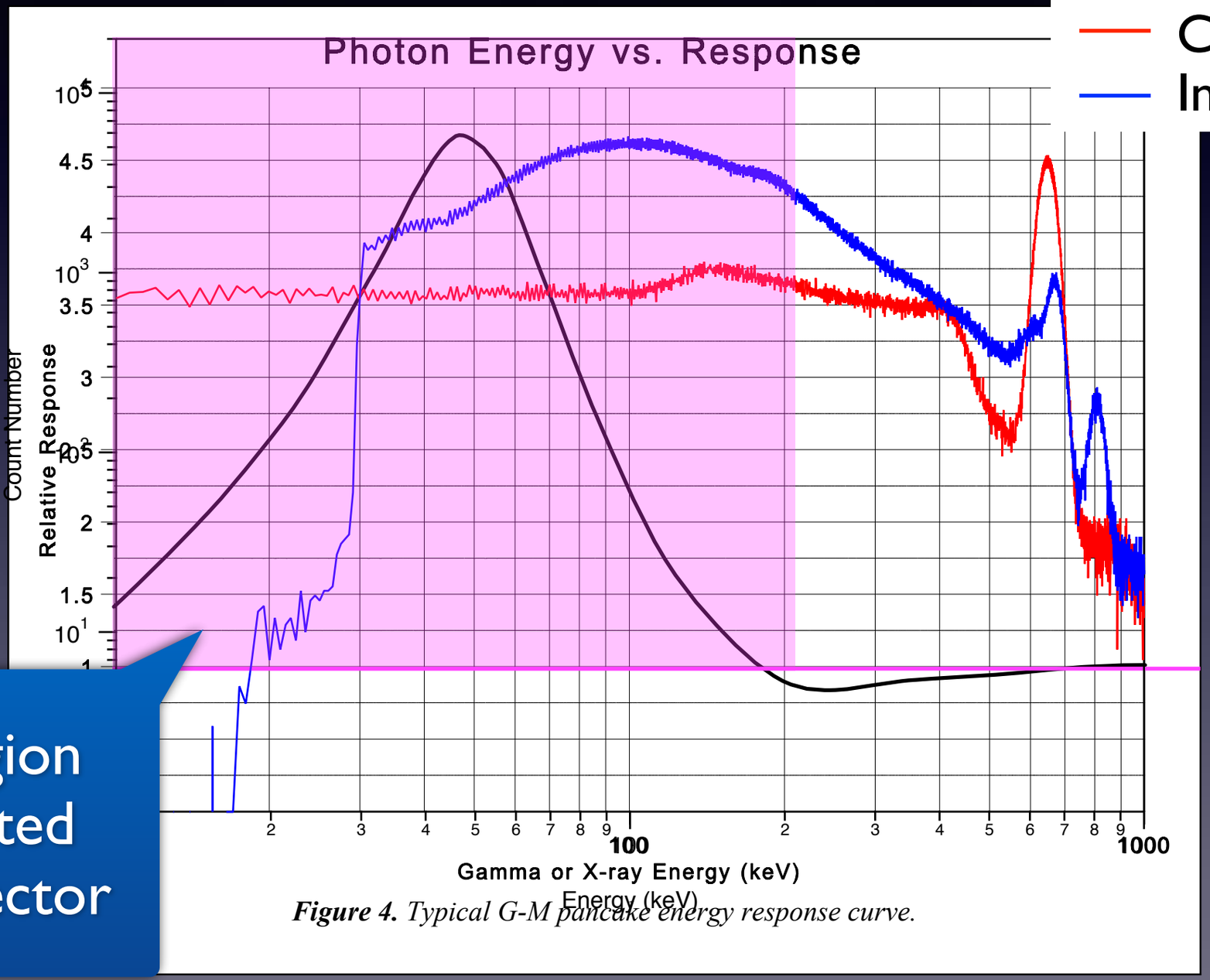


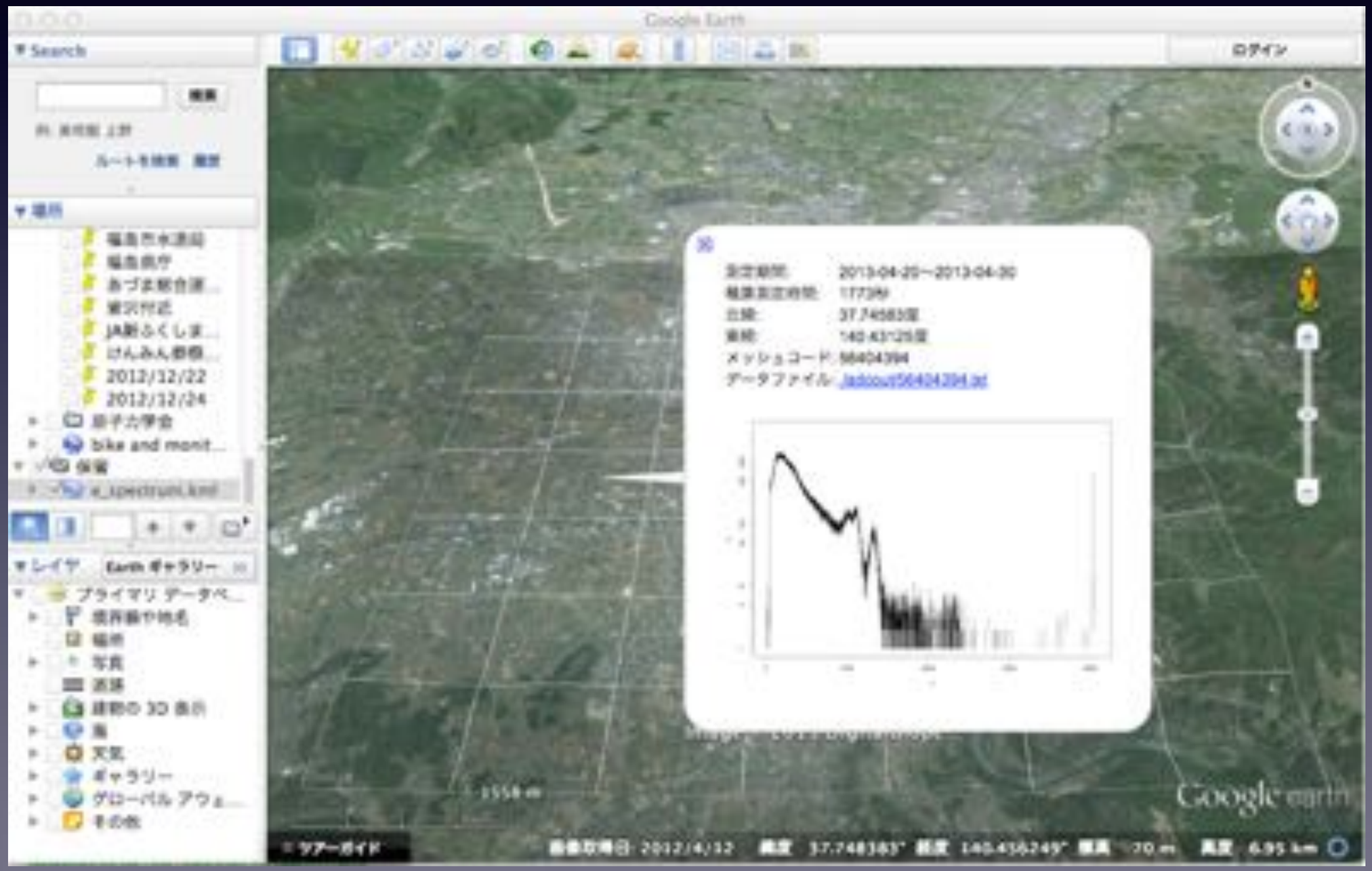
Figure 4. *Typical G-M pancake energy response curve.*

Energy region over-counted by GM detector

Paul R. Steinmeyer, RSO Magazine, 10 (2005) 7

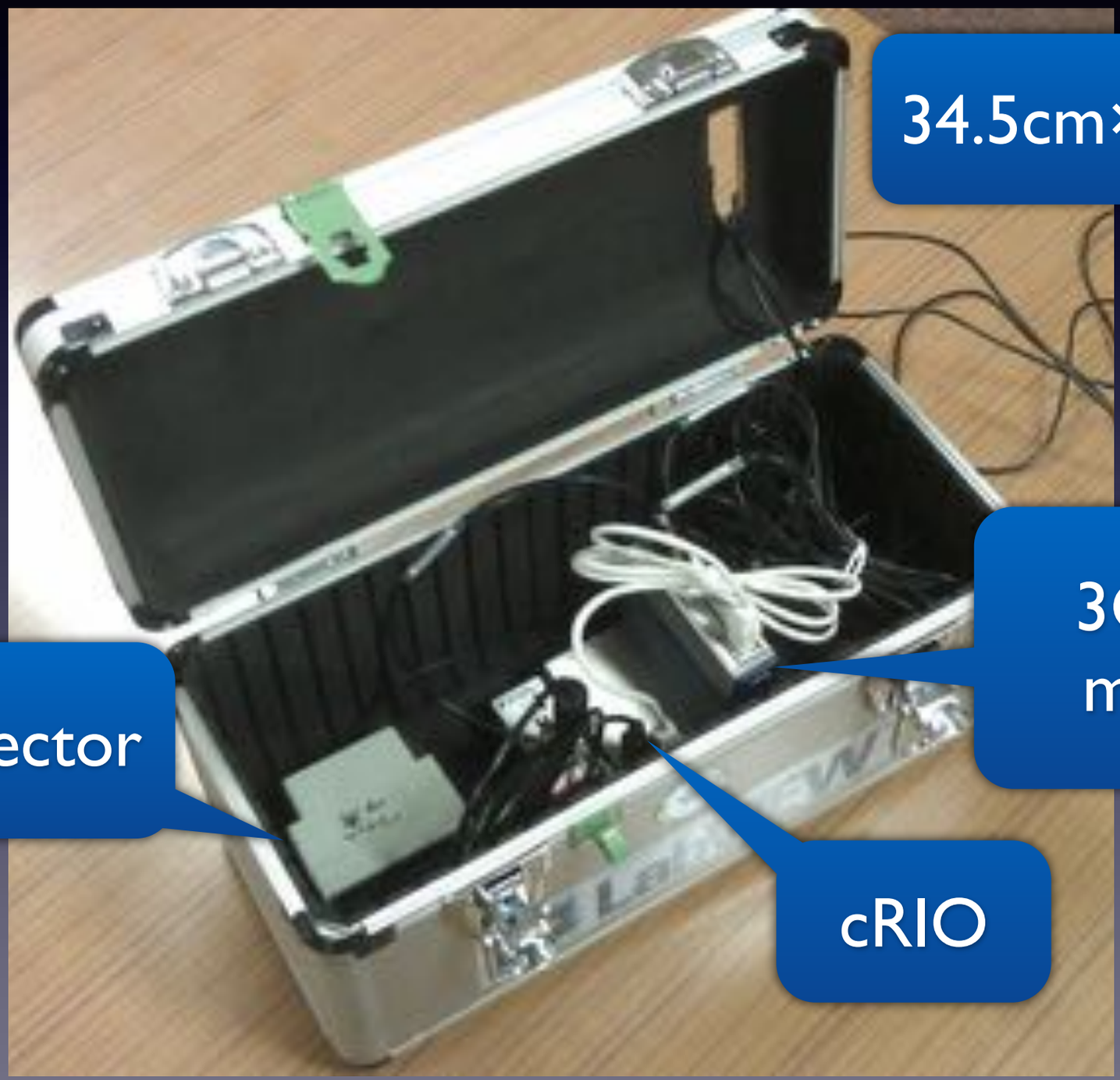
Pulse Height Spectra

Taken at every measurement point, tagged by GPS data, stored in the database for reconstruction



KURAMA-II

Compact & autonomous spectrometry system



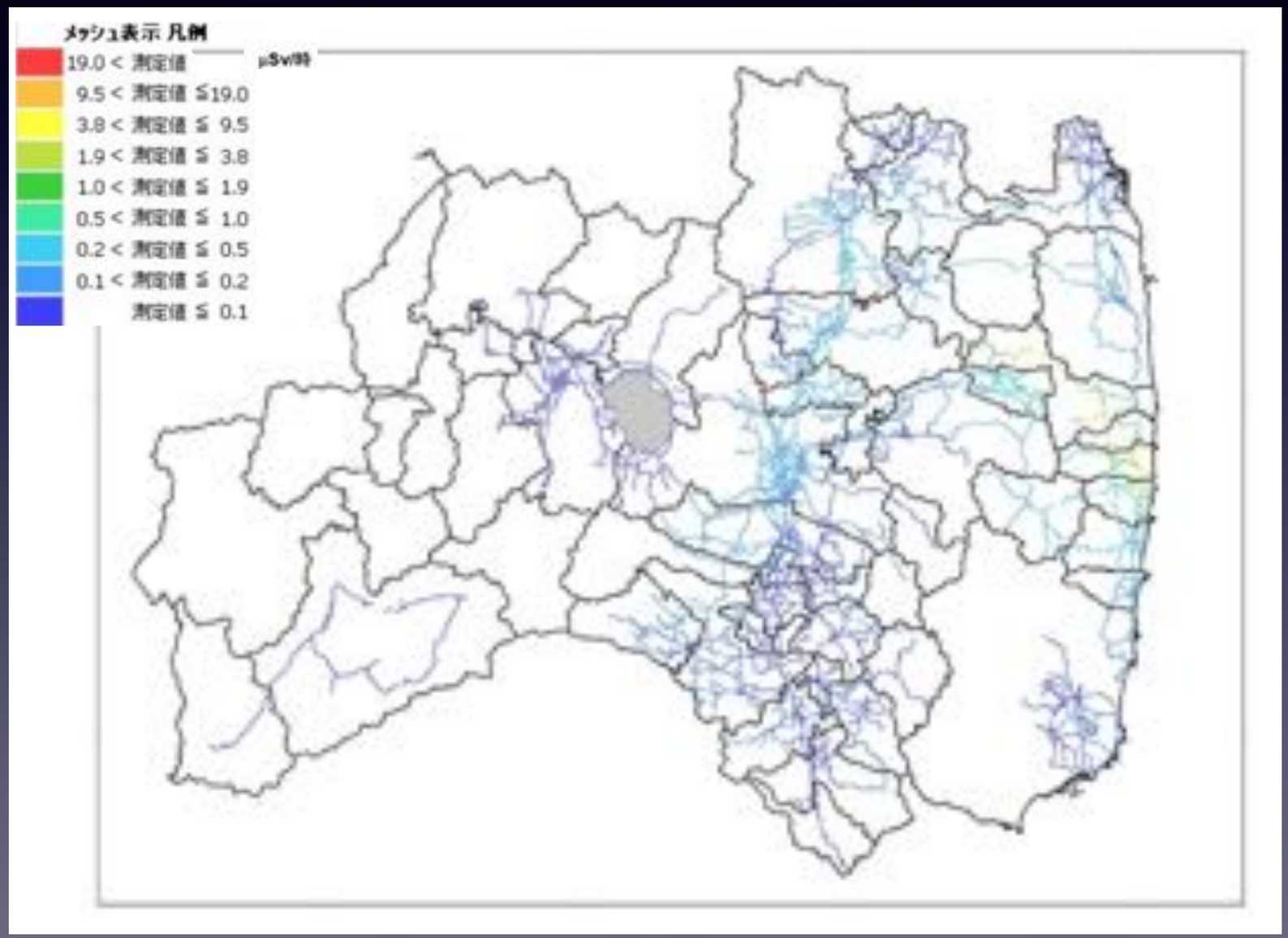
What we have done with KURAMA-II

KURAMA-II on Local Bus

In cooperation with Fukushima Kotsu Co. Ltd. (2011~)

Current Status

50 local buses etc. are operated daily in whole prefecture

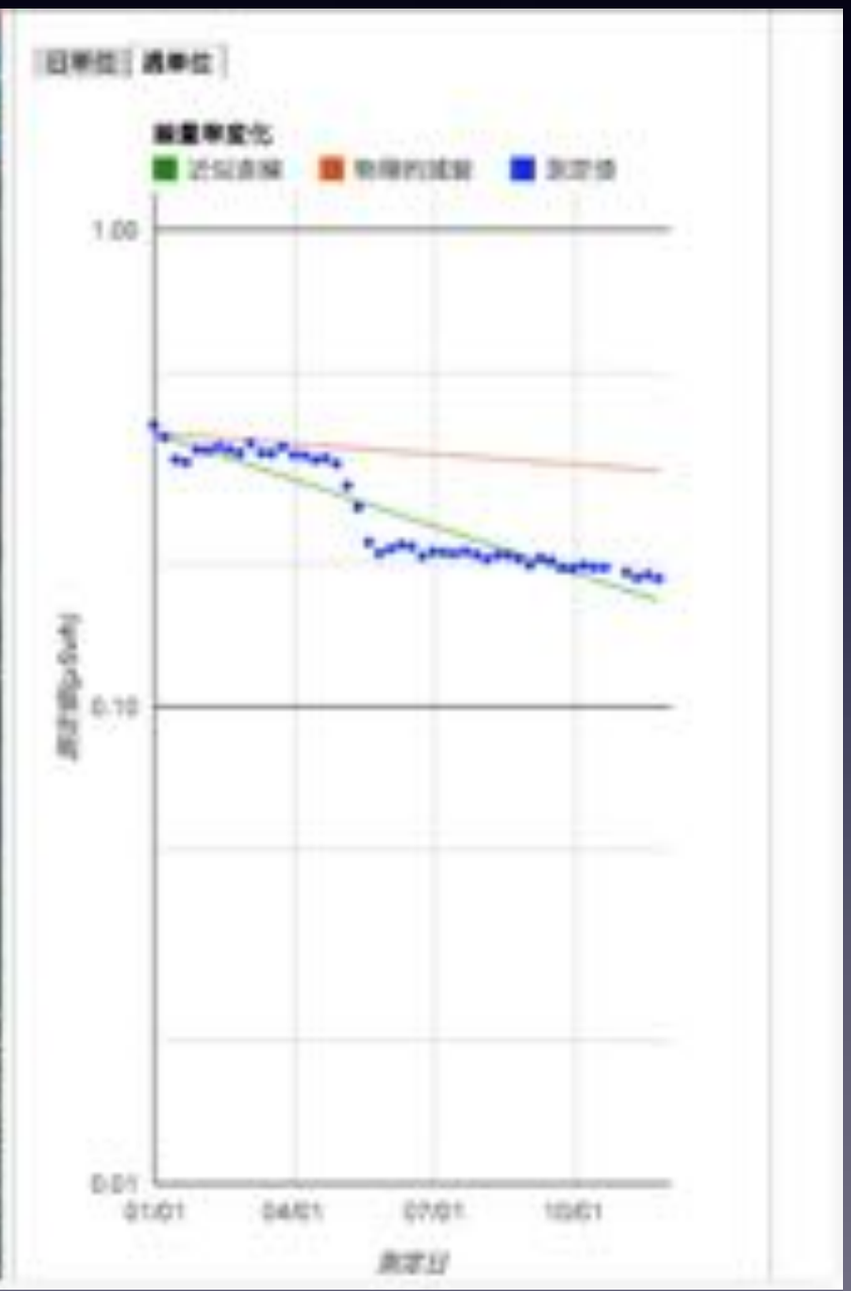


Cooperative project :
Fukushima prefecture
JAEA
Kyoto University

http://www.pref.fukushima.lg.jp/sec/16025d/soukou.html (in Japanese)

Monitoring by KURAMA-II

Confirm the effect of decontamination



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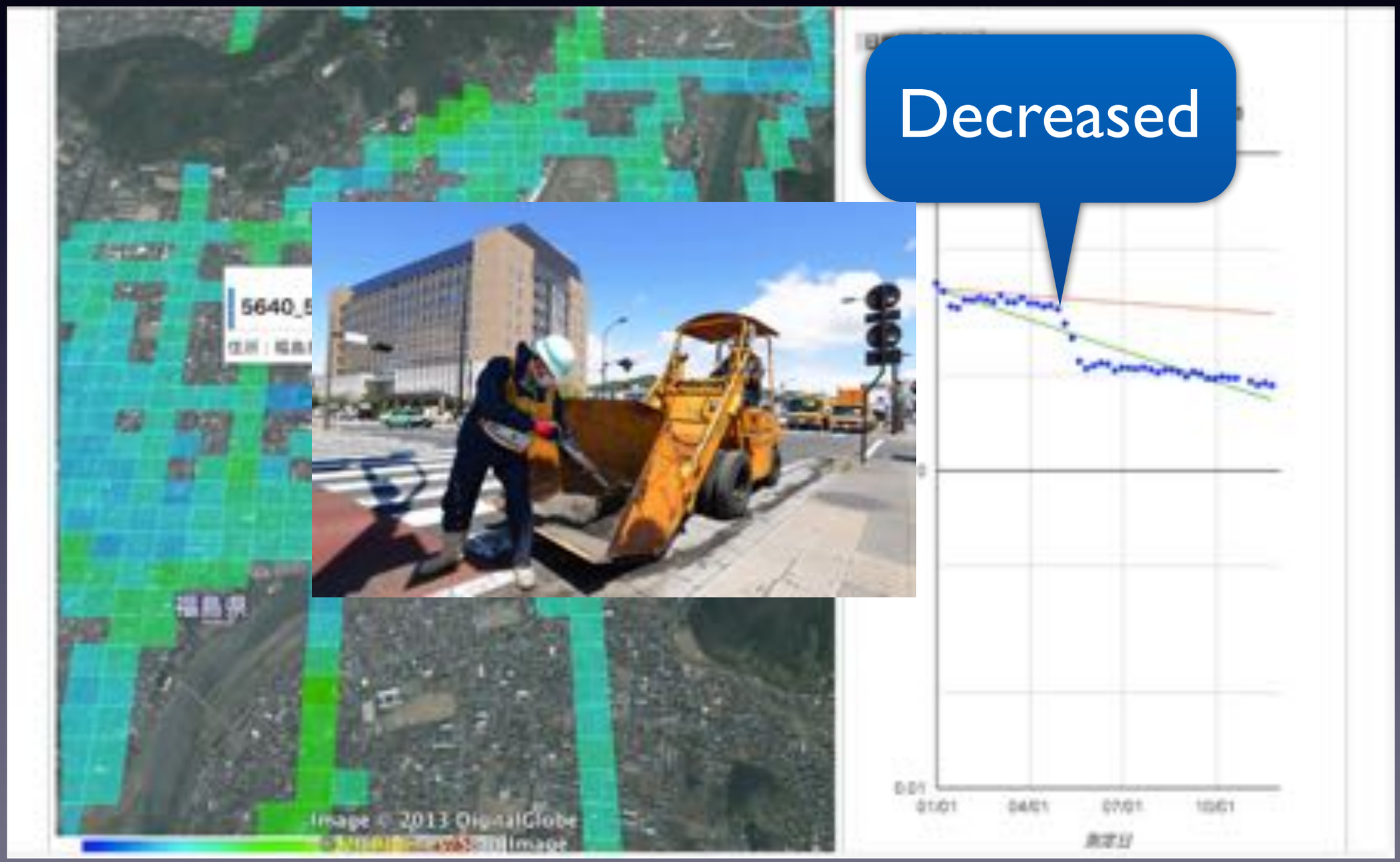

Monitoring by KURAMA-II

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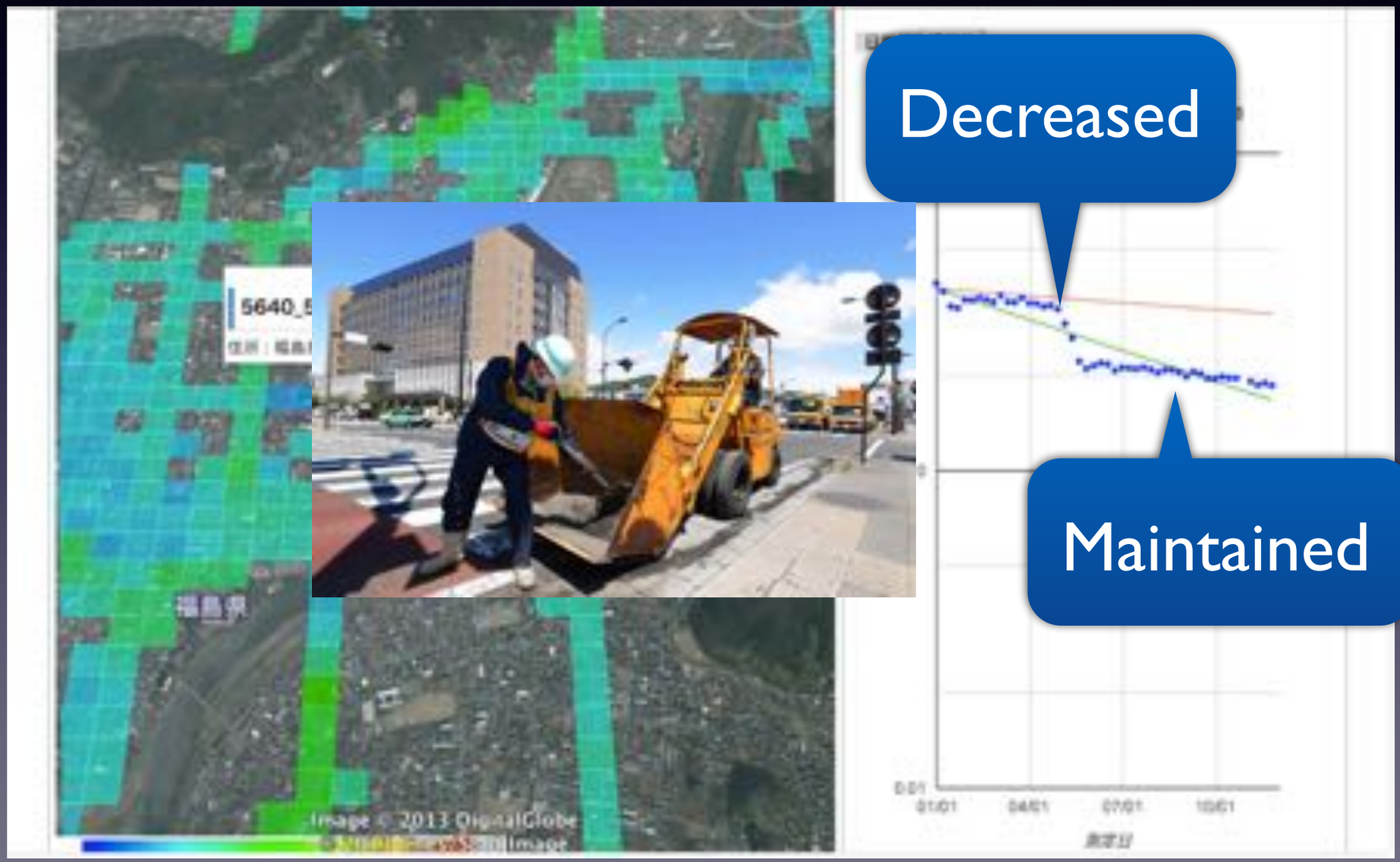
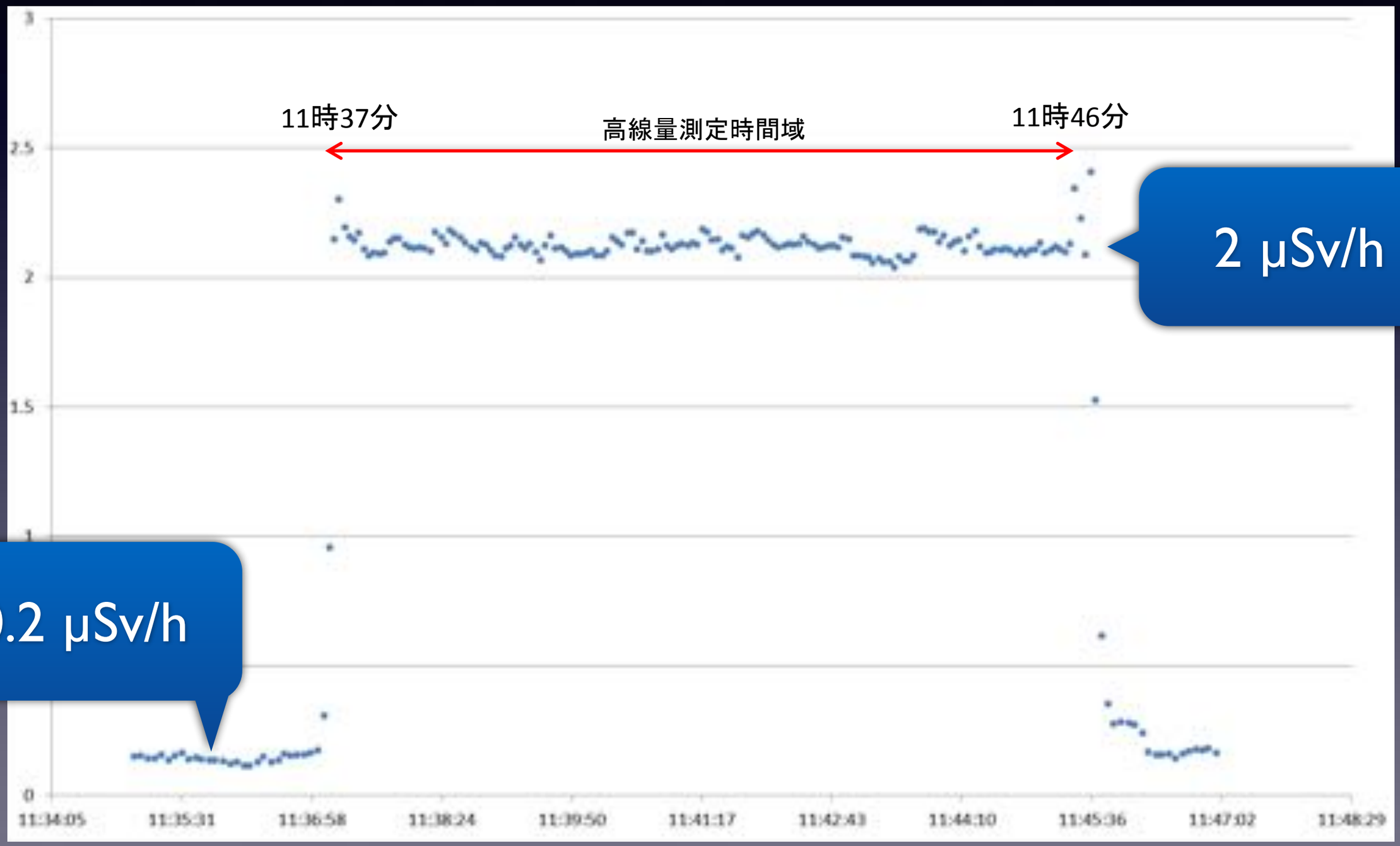


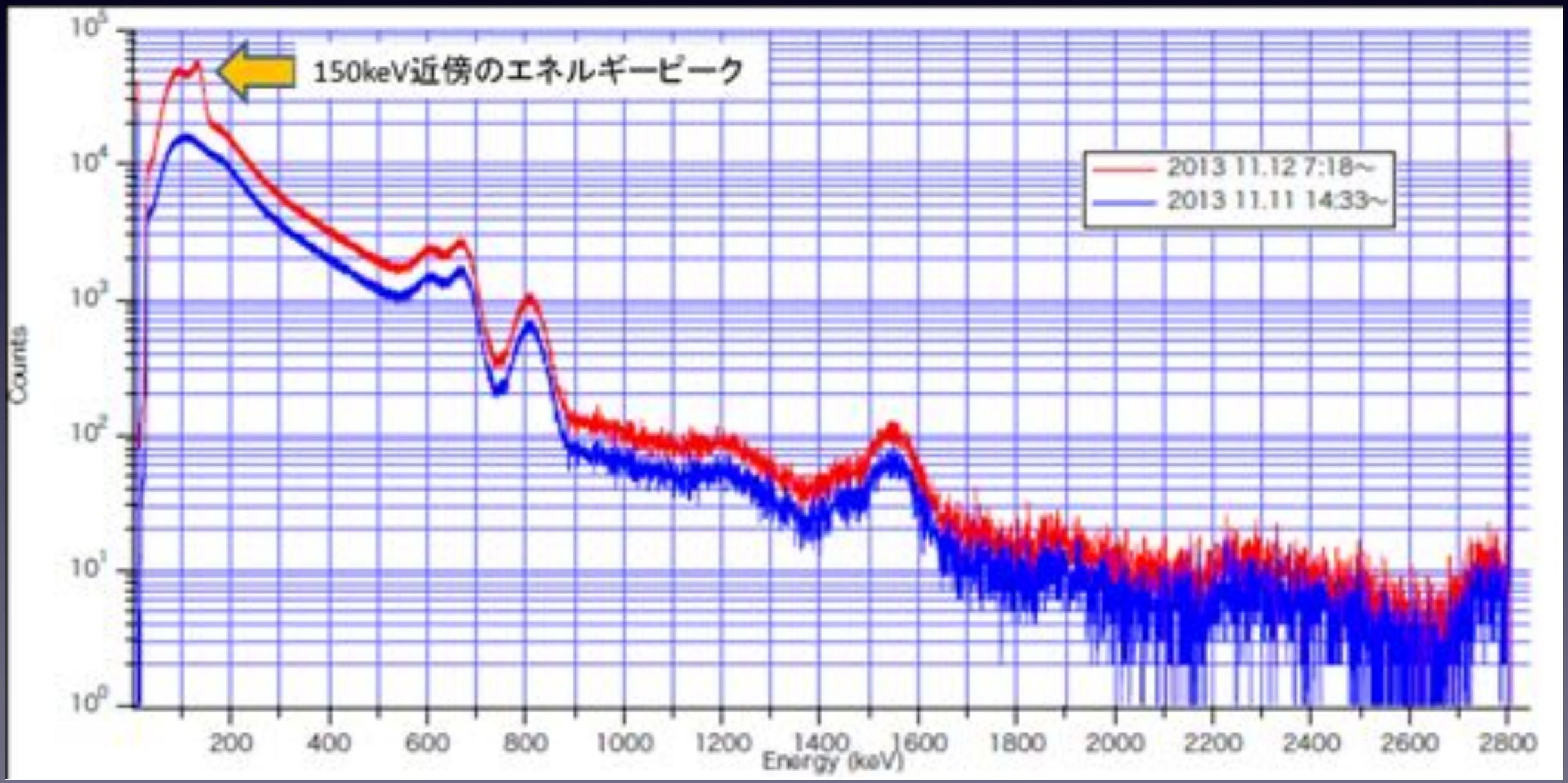
Radiopharmaceuticals

Sudden increase between a hospital and its nearest station



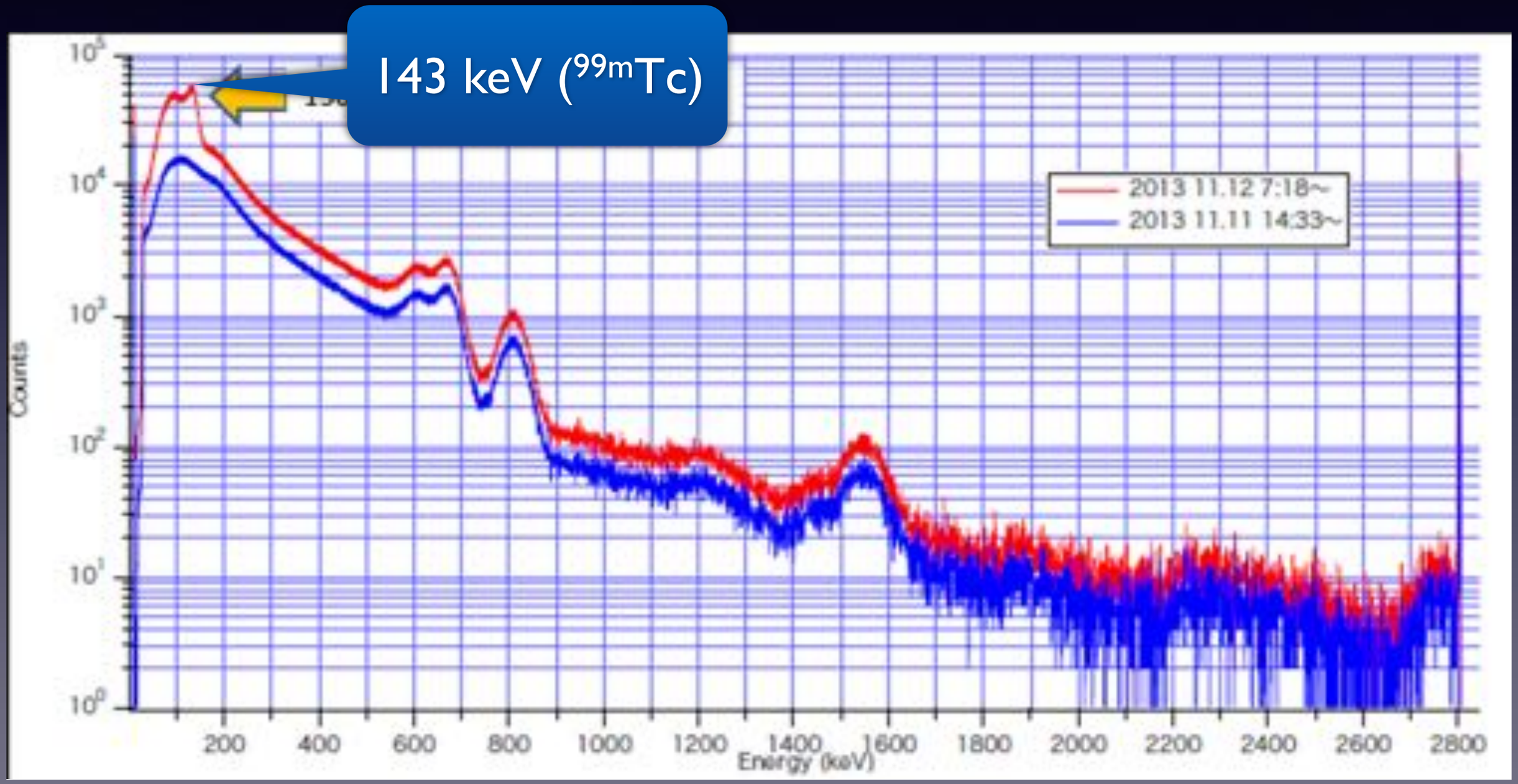
Pulse Height Spectra by KURAMA-II

143 keV peak of ^{99m}Tc was identified



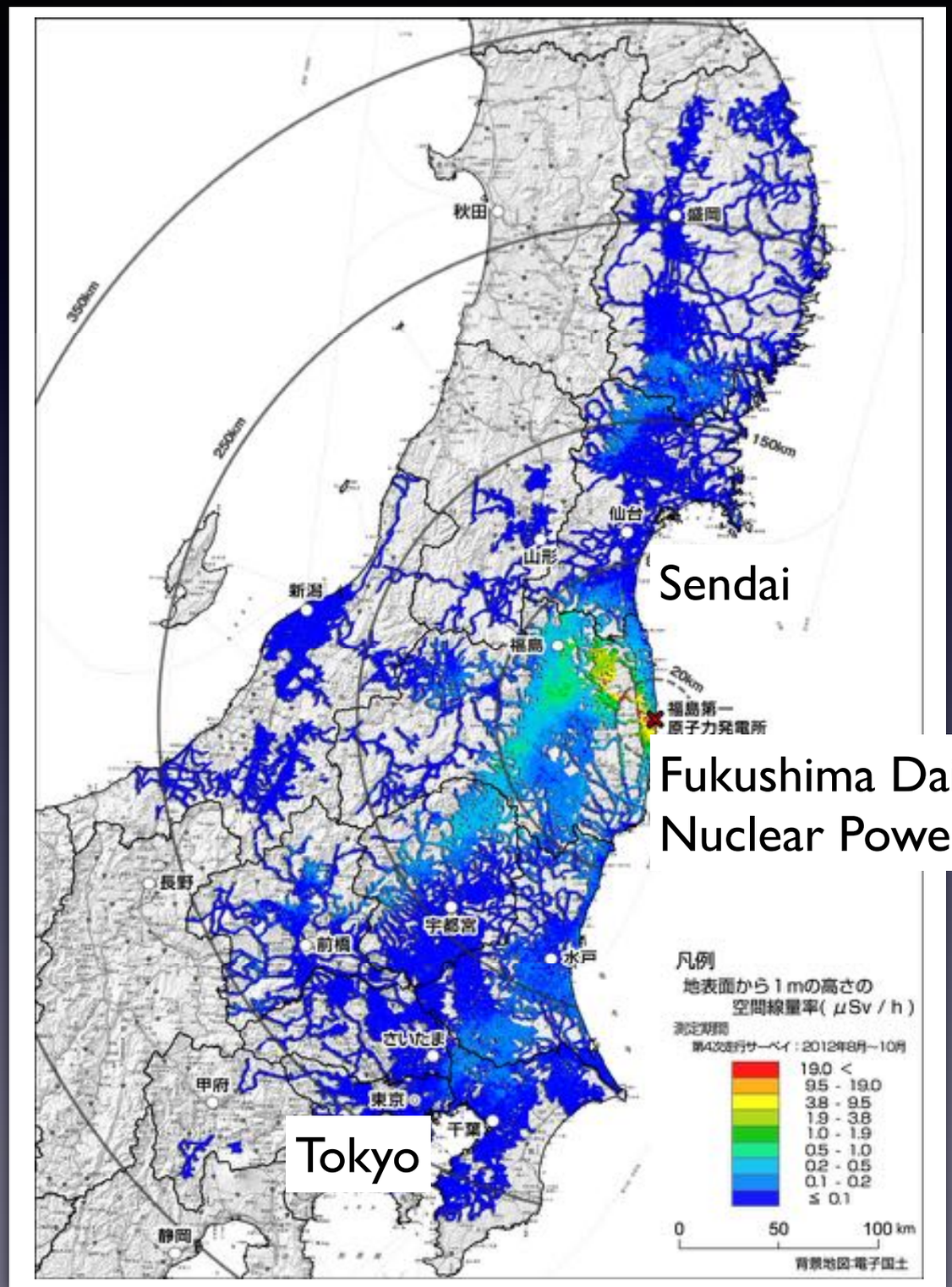
Pulse Height Spectra by KURAMA-II

143 keV peak of ^{99m}Tc was identified



Large Scale Survey by KURAMA-II

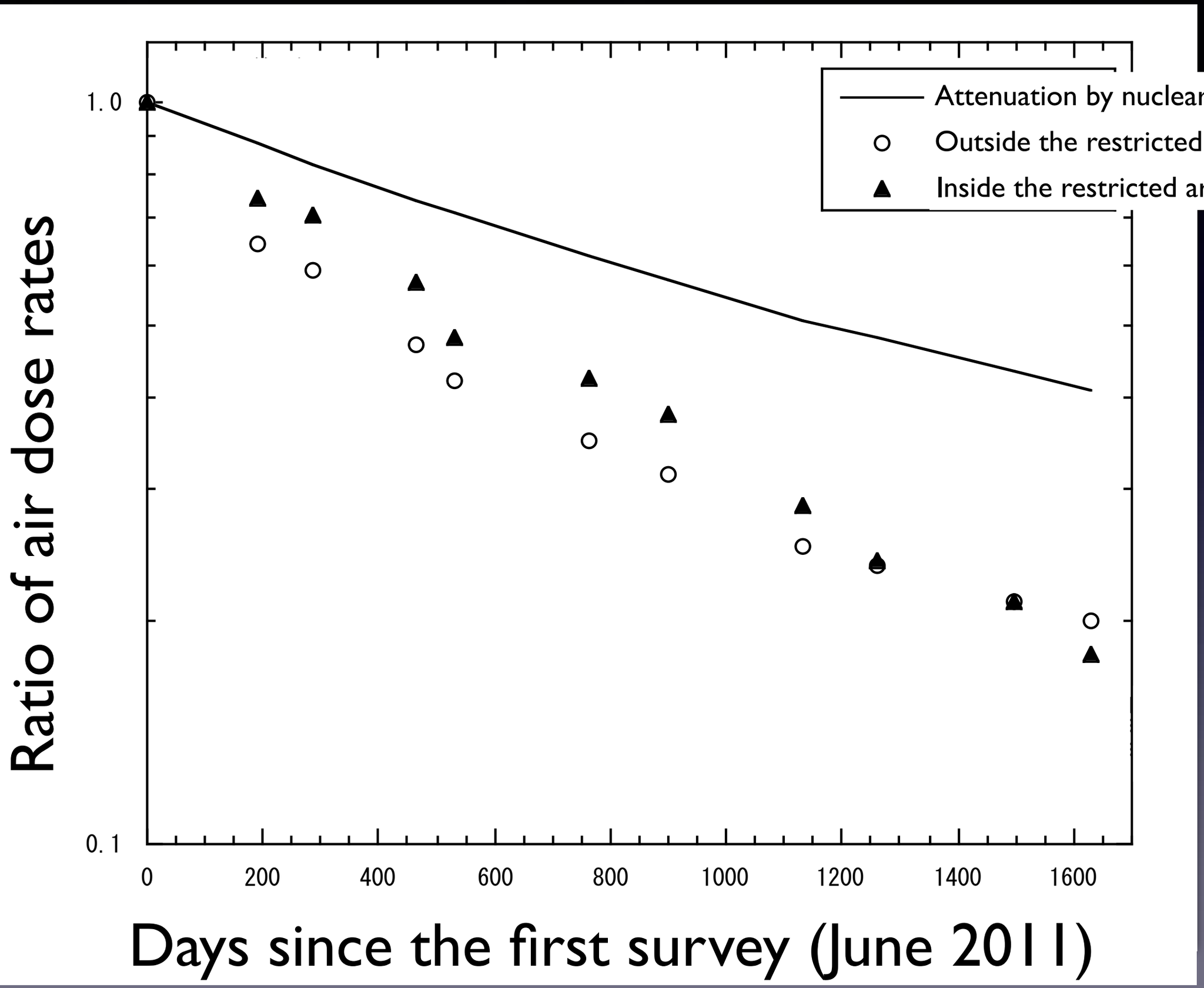
(March 2012~)



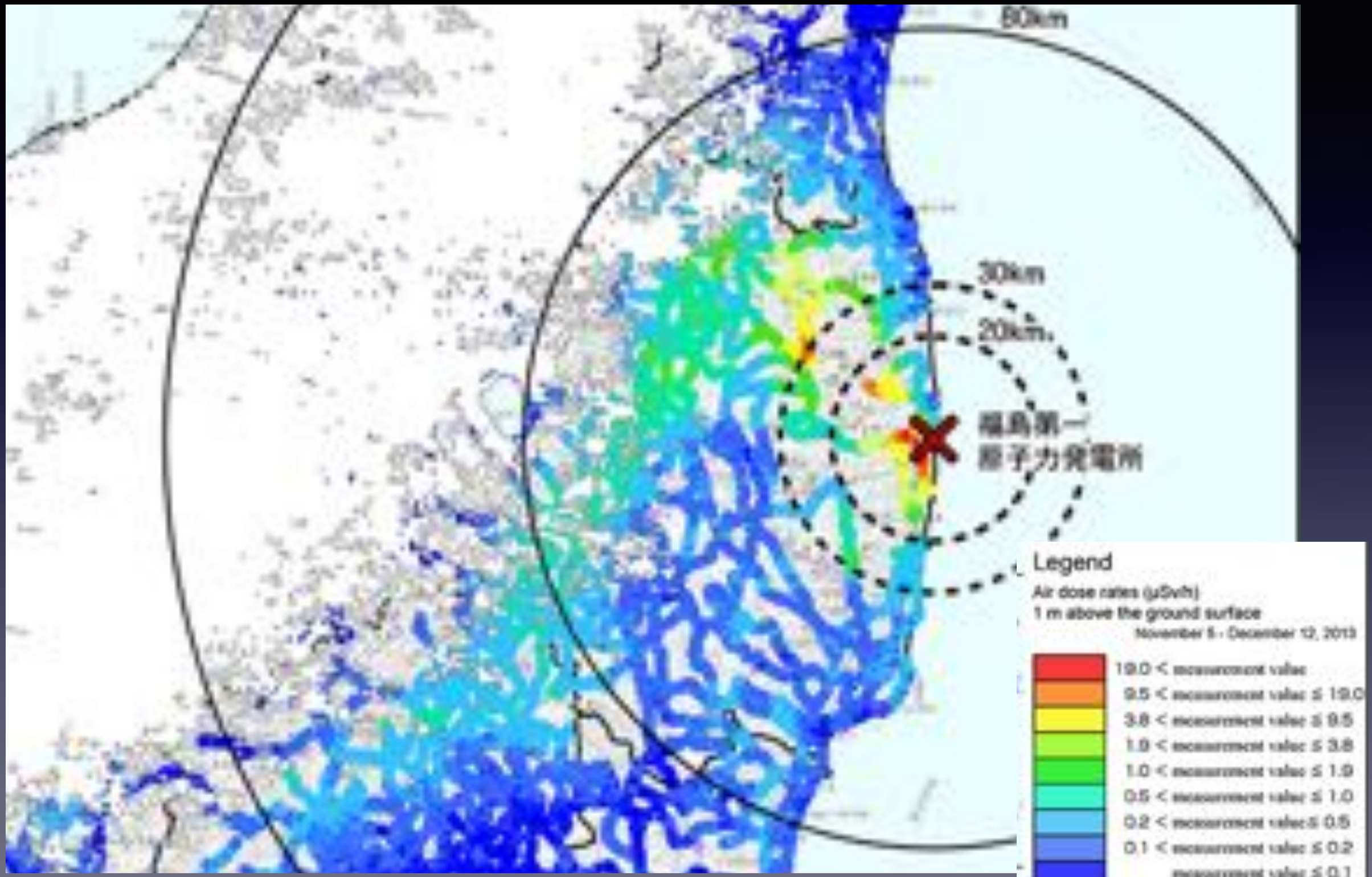
- Conducted by MEXT and NRA(Nuclear Regulatory Agency)
- More than 100 KURAMA-II operated by employees of municipalities in eastern Japan

Scalability Proven

http://ramap.jmc.or.jp/map/eng/

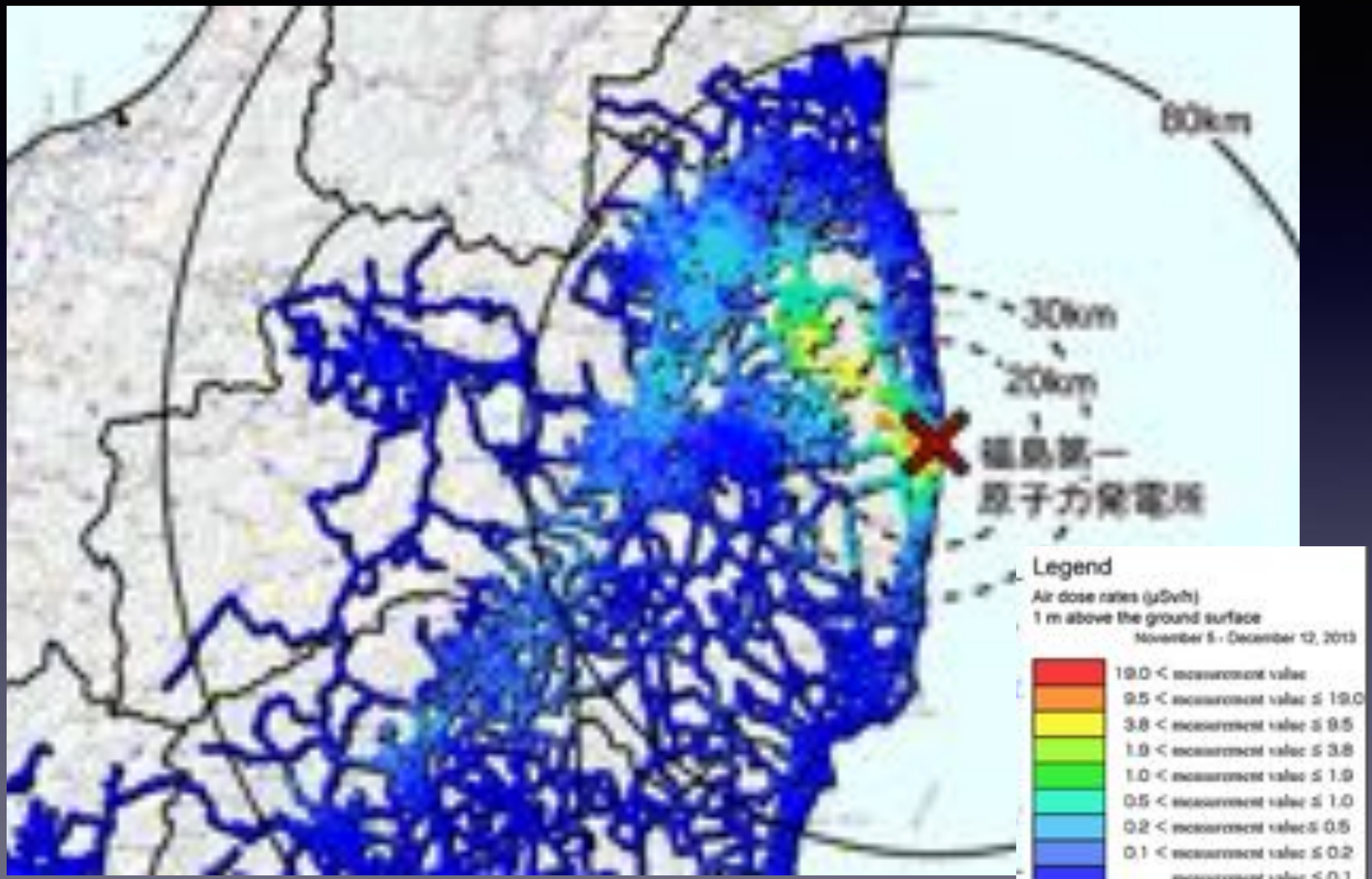

Attenuation by nuclear decay
Outside the restricted area
Inside the restricted area
1.0
0.1
Ratio of air dose rates
0
200
400
600
800
1000
1200
1400
1600
Days since the first survey (June 2011)

March 2012



Extension site of distribution map of radiation dose, etc.
http://ramap.jmc.or.jp/map/eng/

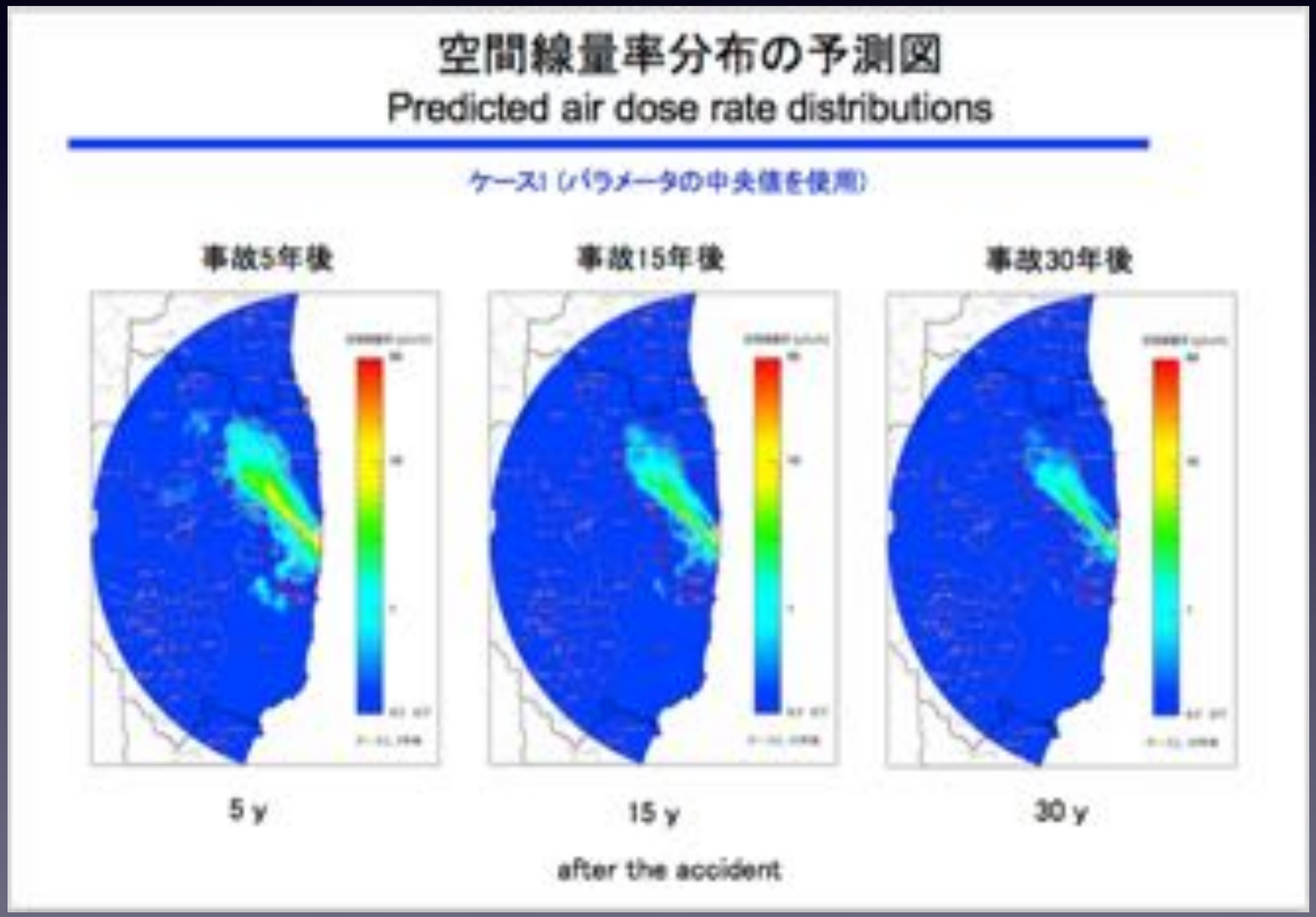
November 2015



Extension site of distribution map of radiation dose, etc.
http://ramap.jmc.or.jp/map/eng/

Long Term Prediction

Data from KURAMA-II is used for parametrization



Kinase et al. (JAEA)

Ongoing challenges with KURAMA-II

Measurement of Soil Contamination

Important for the recovery of agriculture in Fukushima

Internal Exposure through Food

Well controlled in Japan, eventually no risk

100% of brown rice harvested in Fukushima in 2016

Maximum limit (Japan)

1 mSv/year

100 mSv/year

Maximum limit (EU)

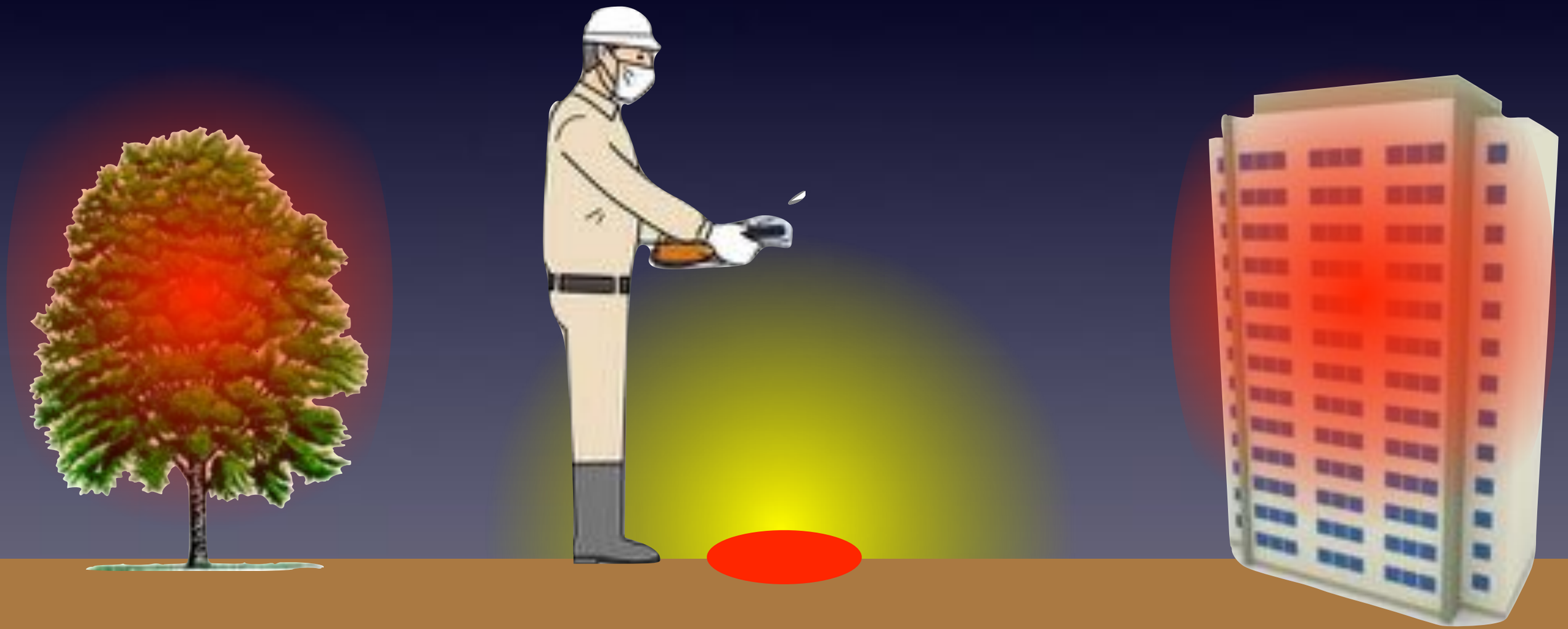
Maximum limit (U.S.)

“Measuring Soil Contamination”

Radiation from surroundings is not negligible

“Measuring Soil Contamination”

Radiation from surroundings is not negligible

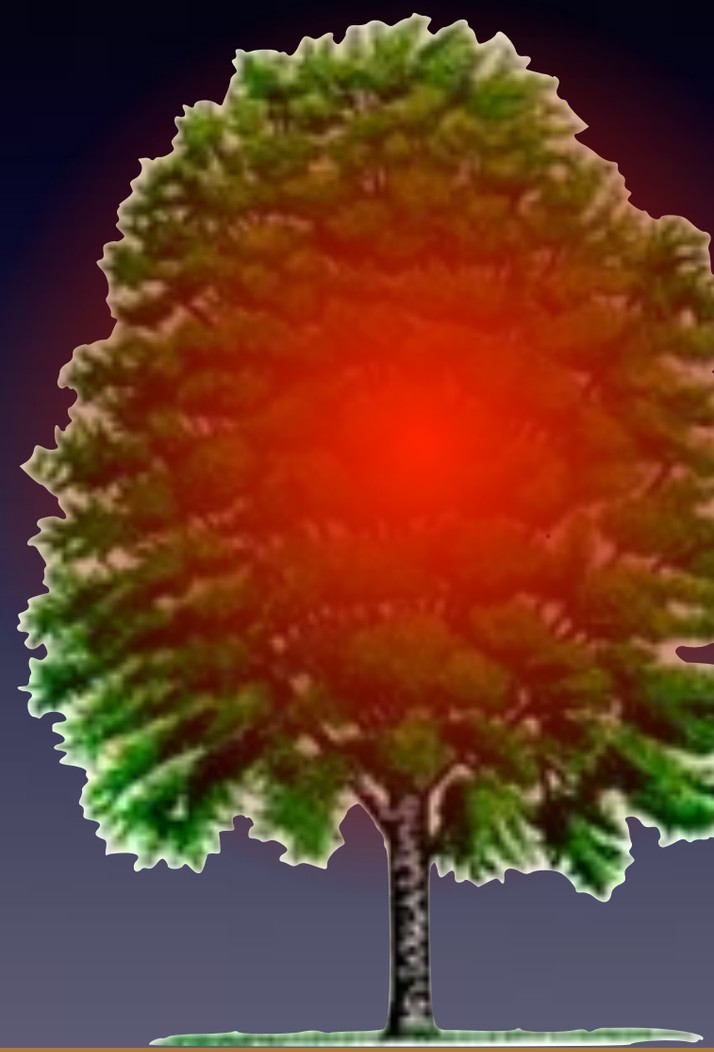


KURAMA-II for Soil Contamination

Subtracting contribution from surroundings

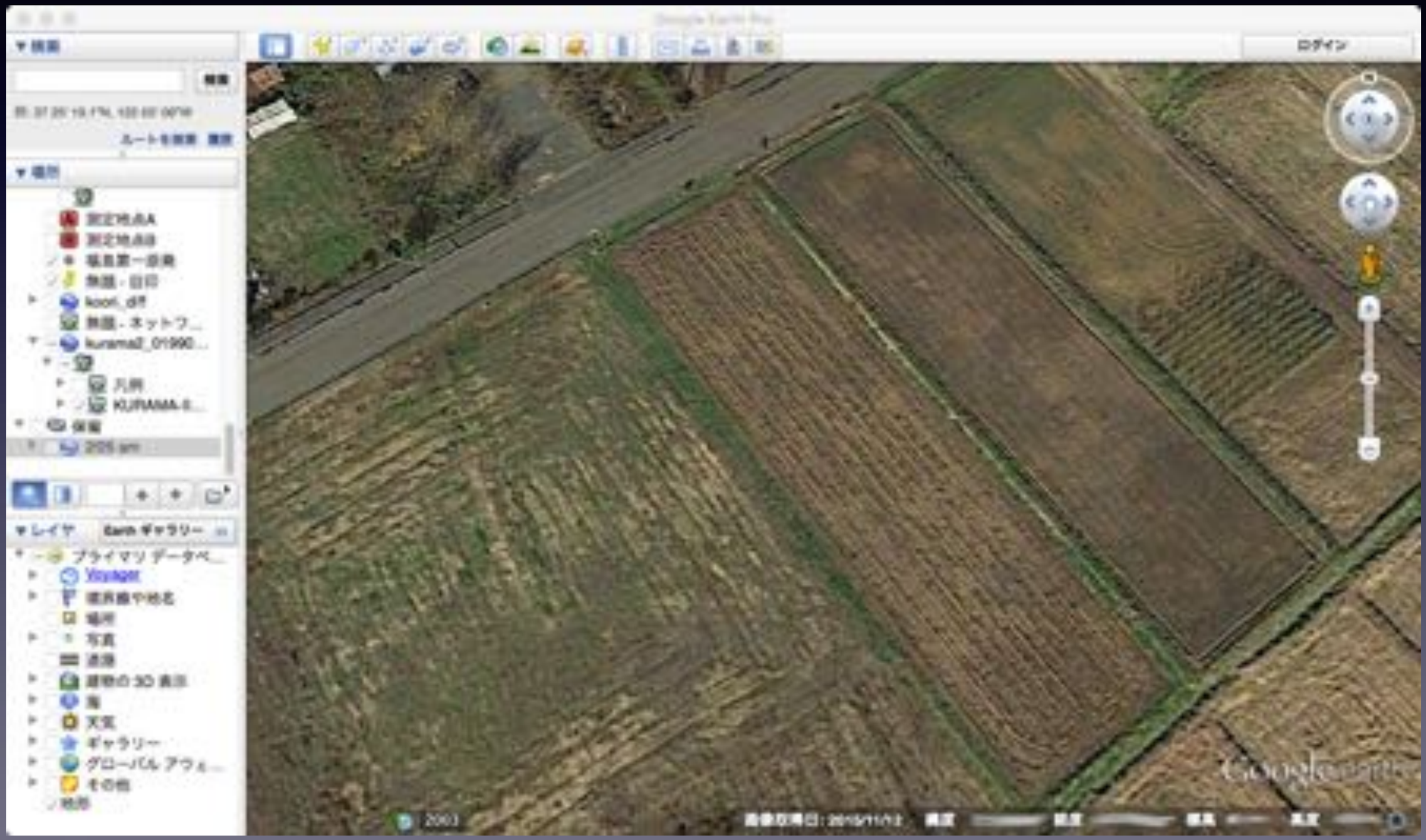
Uncollimated

Collimated
(Solid Angle ~ 1.6π)



Example

Simple, prompt estimation of soil in farmlands

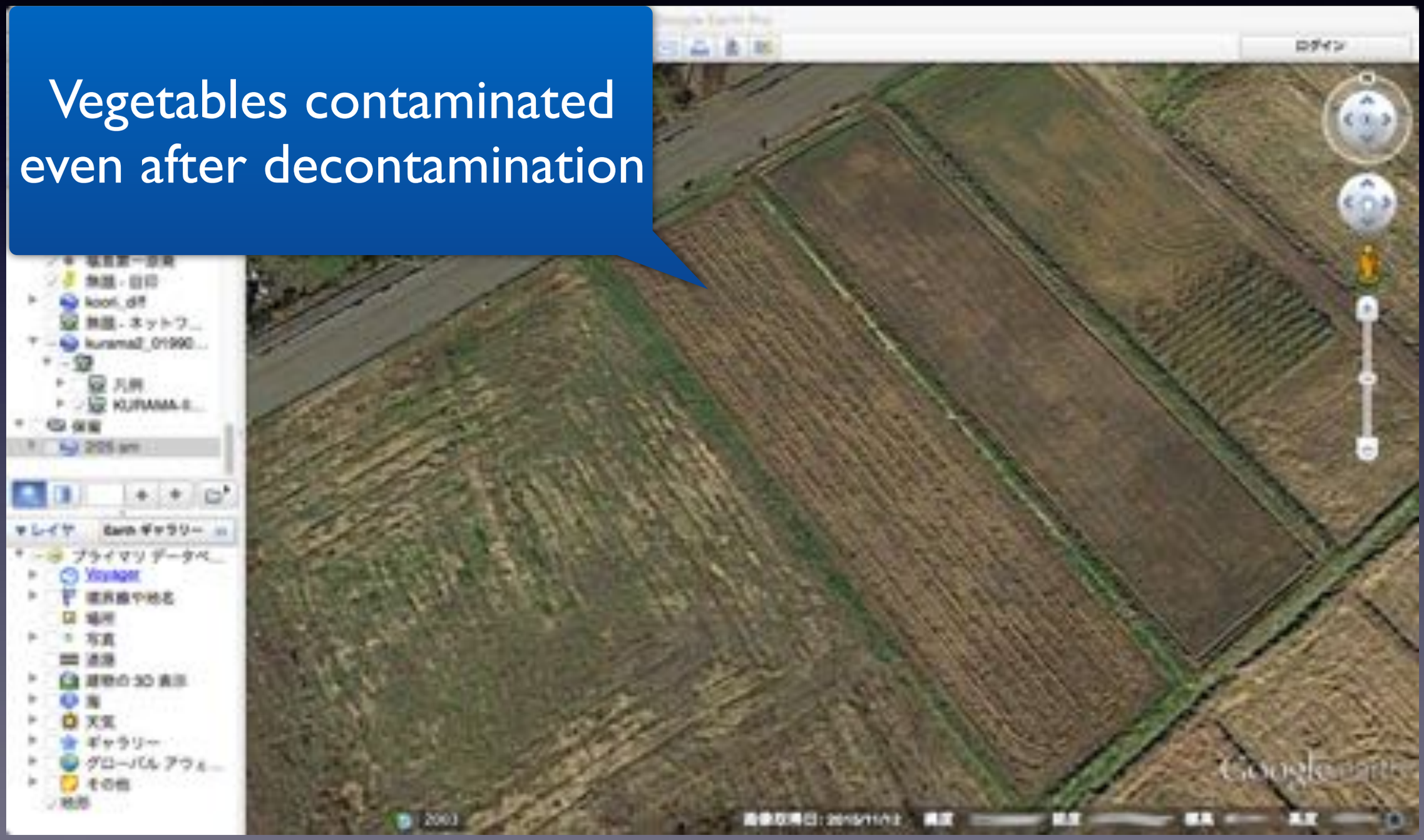


Collaboration with Fukushima Agricultural Technology Center

Example

Simple, prompt estimation of soil in farmlands

Vegetables contaminated even after decontamination

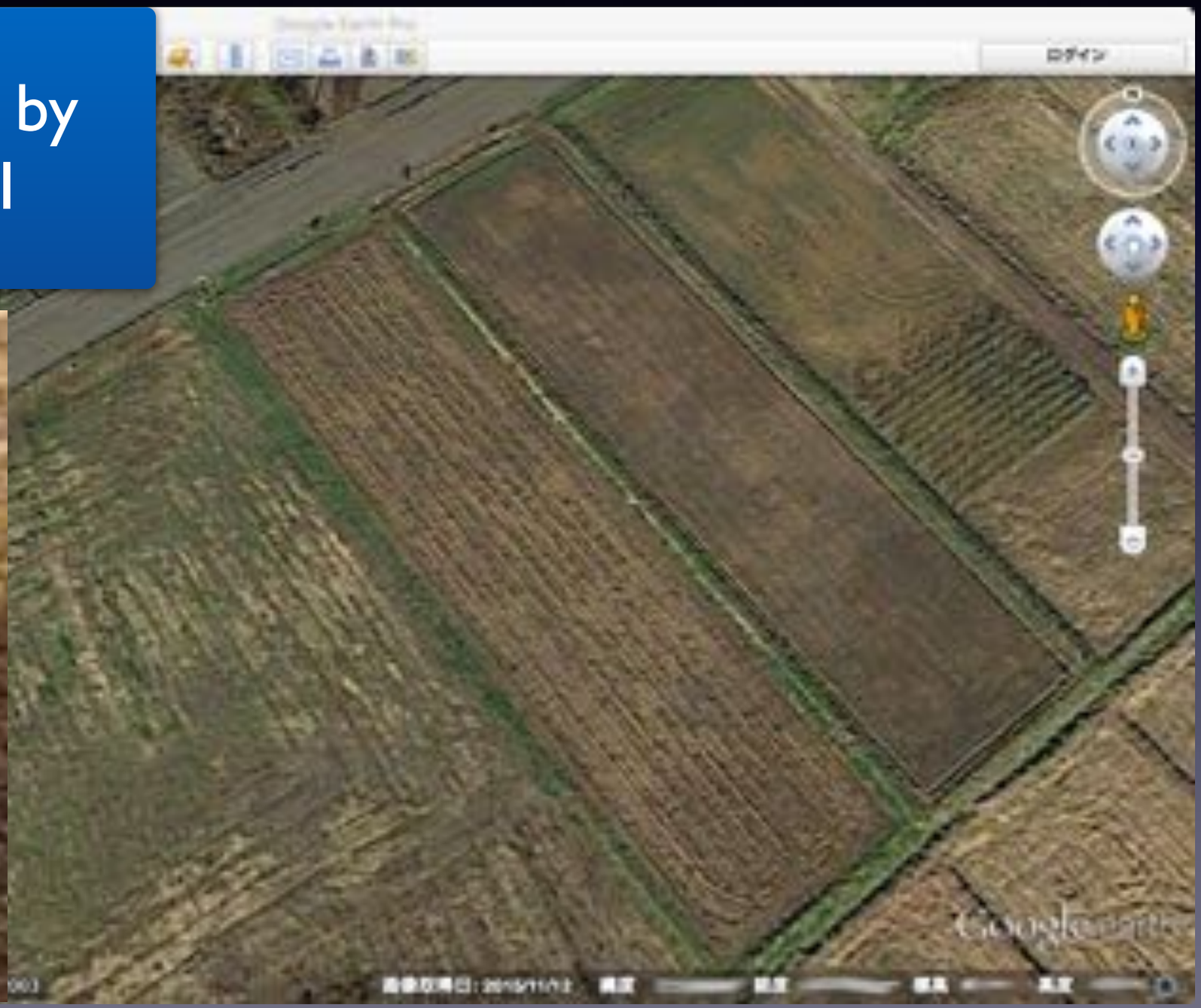


Collaboration with Fukushima Agricultural Technology Center

Example

Simple, prompt estimation of soil in farmlands

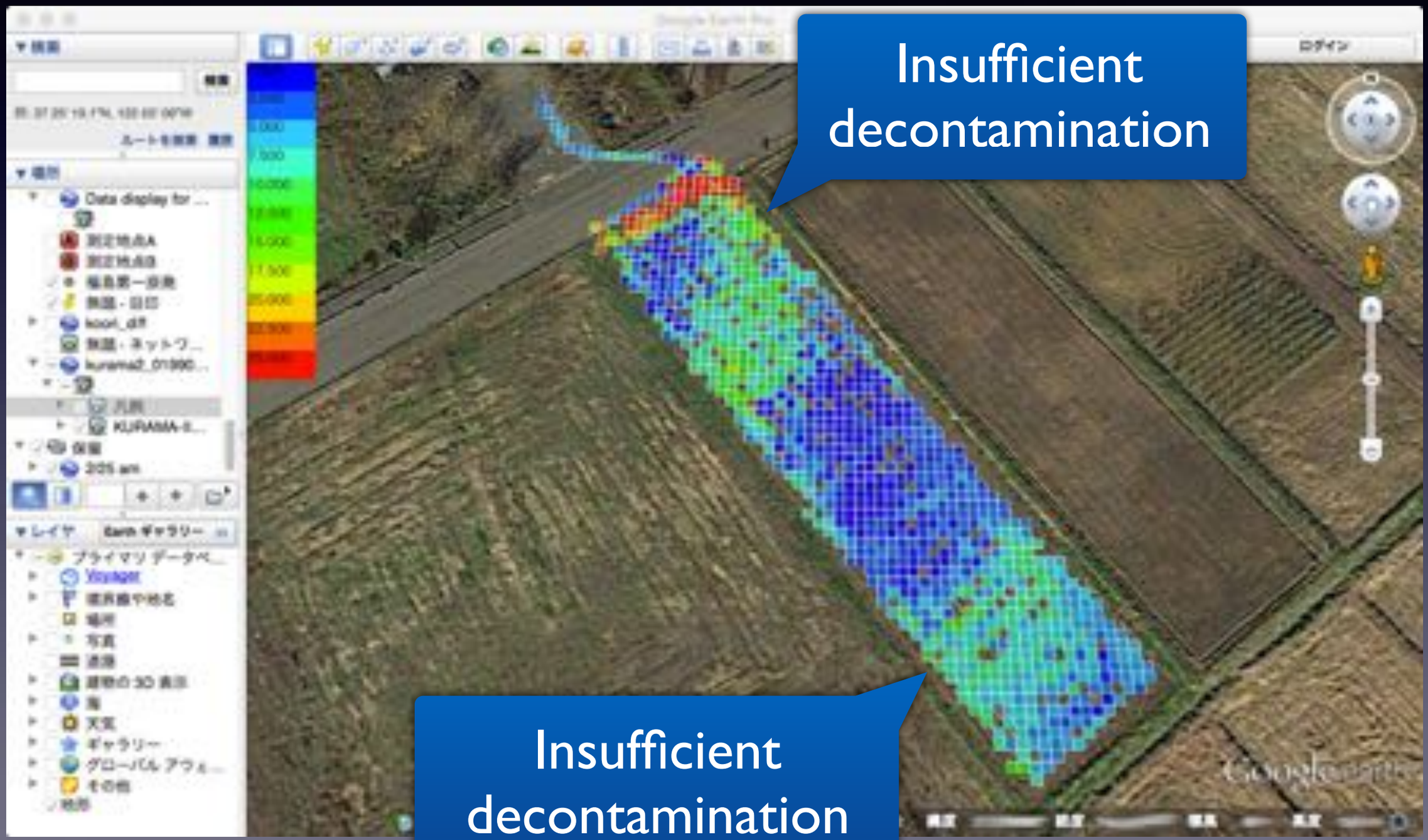
Measurement by KURAMA-II



Collaboration with Fukushima Agricultural Technology Center

Example

Simple, prompt estimation of soil in farmlands



Collaboration with Fukushima Agricultural Technology Center

Expected Usage

Collecting the data on soil contamination

Internet/
Cloud

Surveys in farmlands, residential areas

Advices by specialists based on shared data

For Emergency

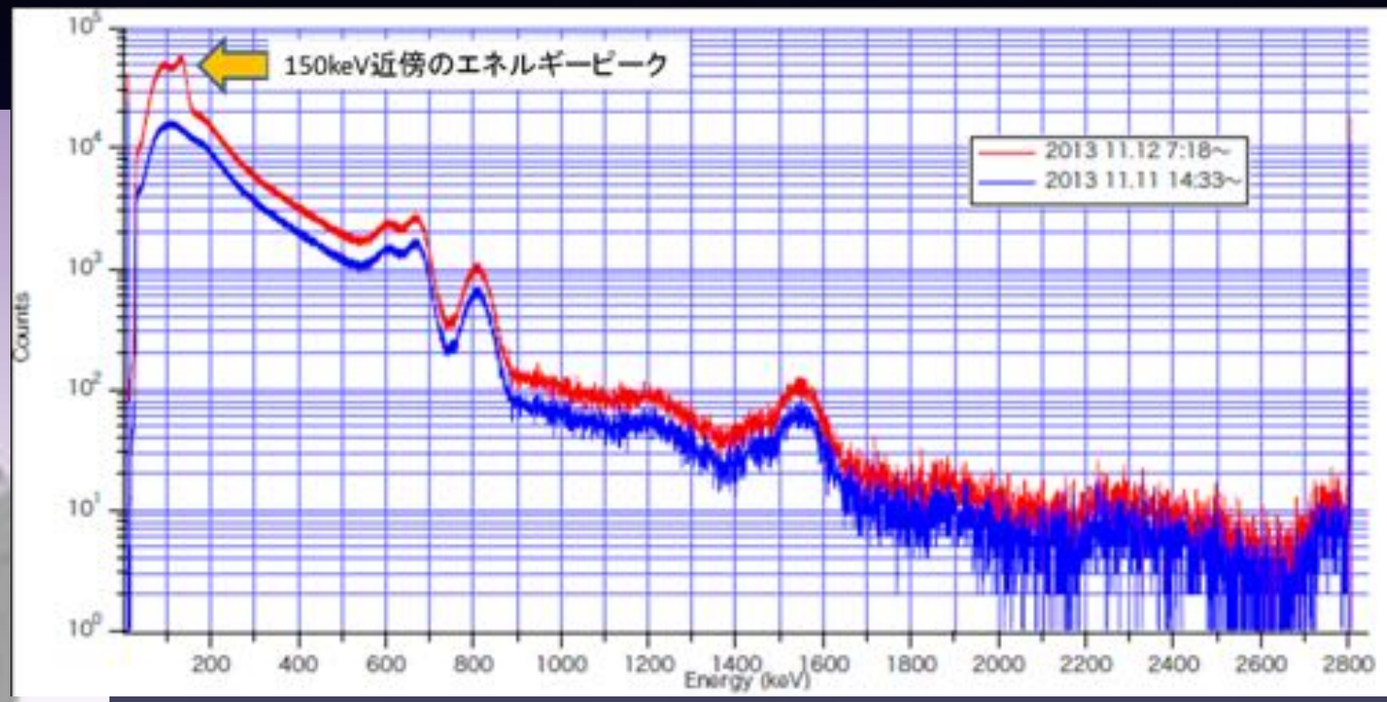
Survey meter with KURAMA-II function

KURAMA-mini

For Emergency

Survey meter with KURAMA-II function

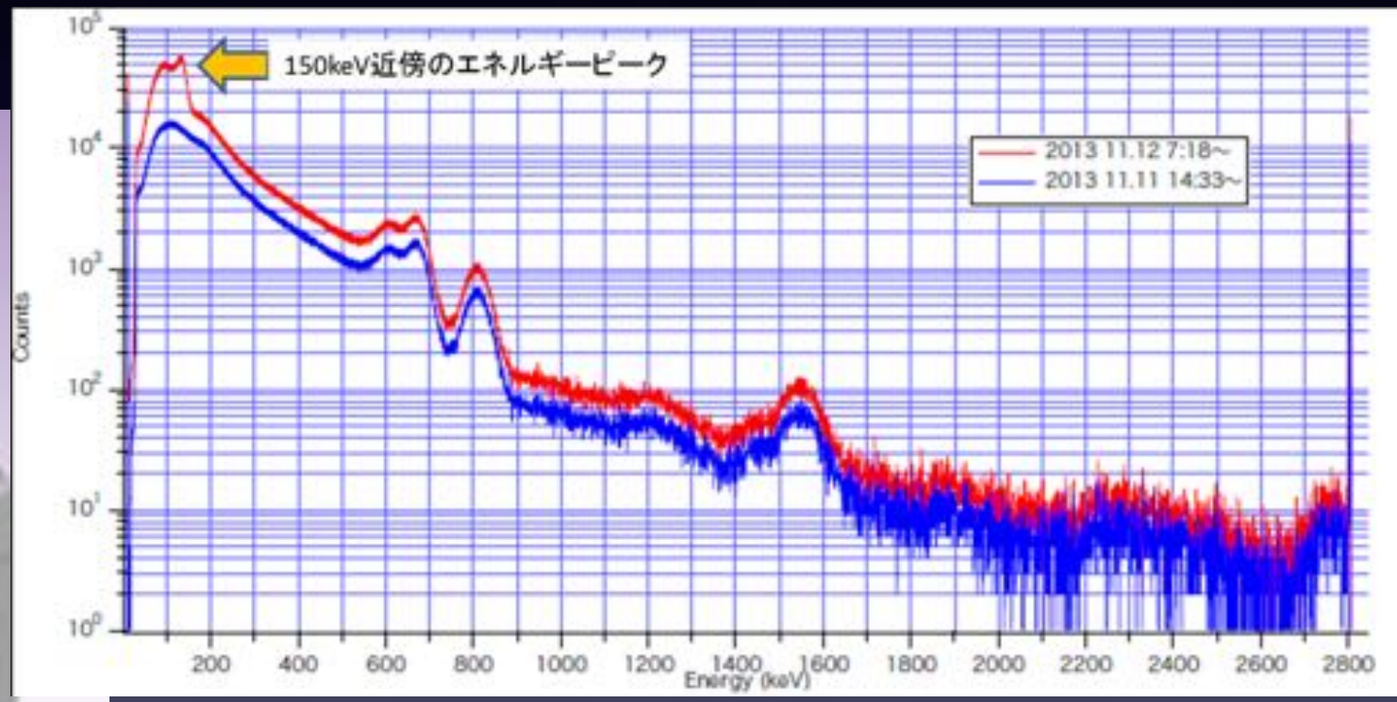
KURAMA-mini



For Emergency

Survey meter with KURAMA-II function

KURAMA-mini

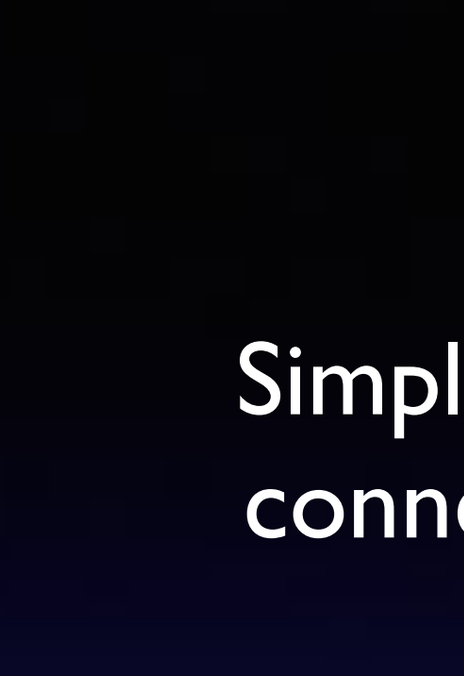


Obtaining spectra
including short-lived nuclei

Example

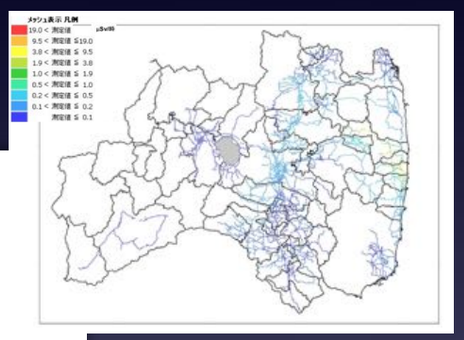
Simplified, standardized system connected with remote places

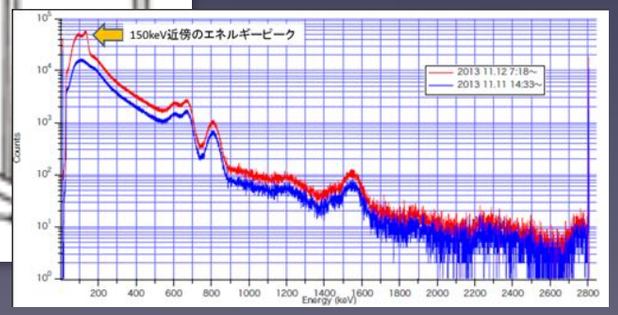
Data



Measurer
(not specialized)

Cloud



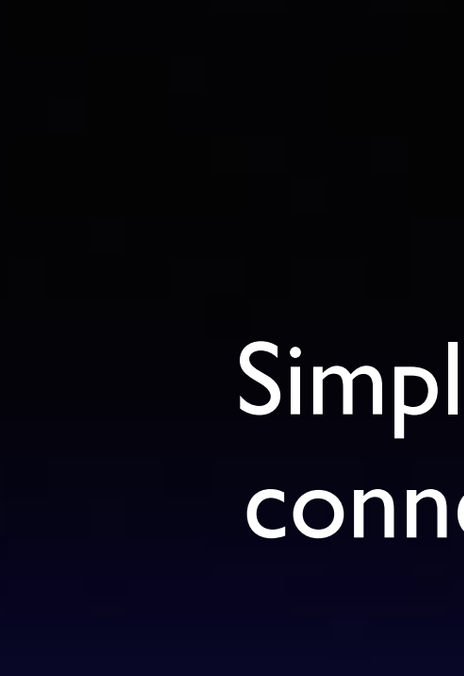


Specialist

Example

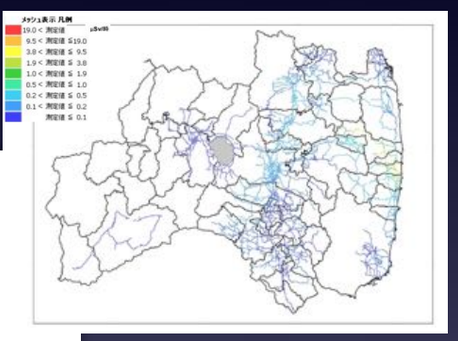
Simplified, standardized system connected with remote places

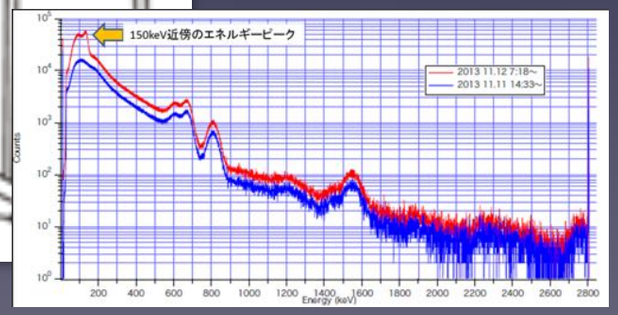
Data



Measurer
(not specialized)

Cloud





Specialist

Control

e.g. : calibration,
measurement modes

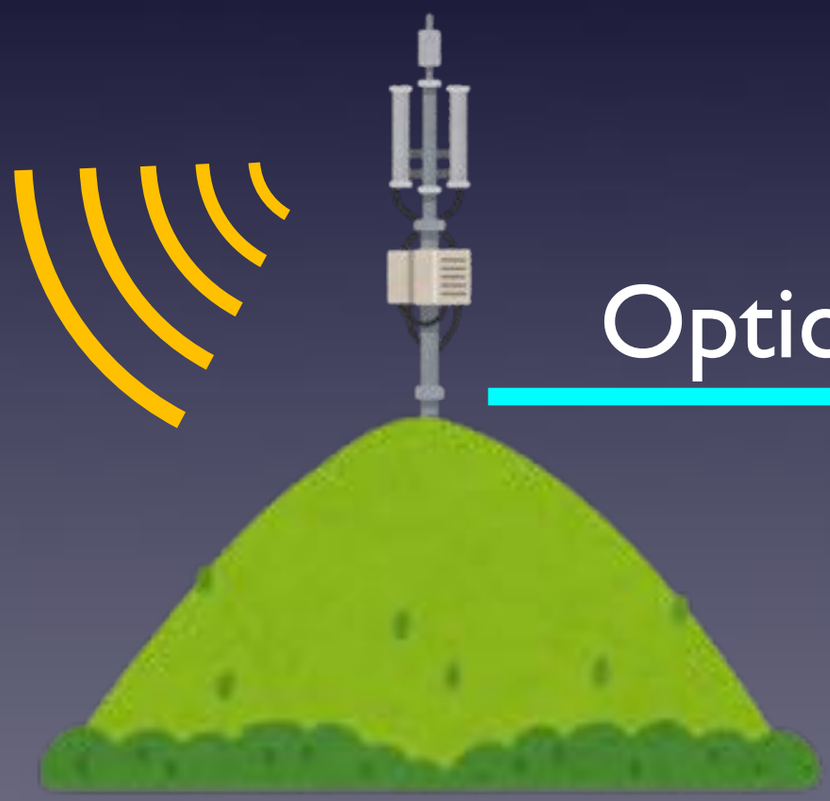
Challenges

More reliable communication under emergency

Satellite Channel

KURAMA-mini

Mobile Network



Optical Fiber

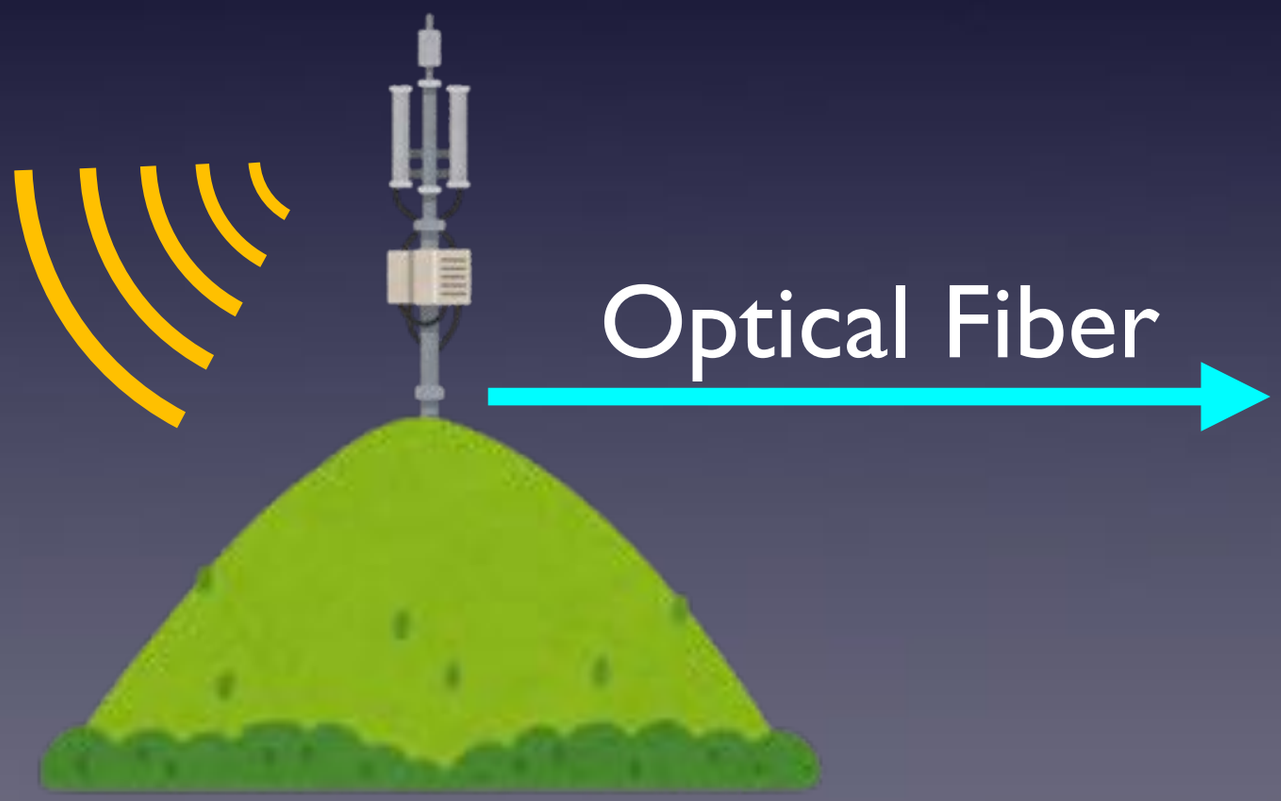
Challenges

More reliable communication under emergency

Satellite Channel

KURAMA-mini

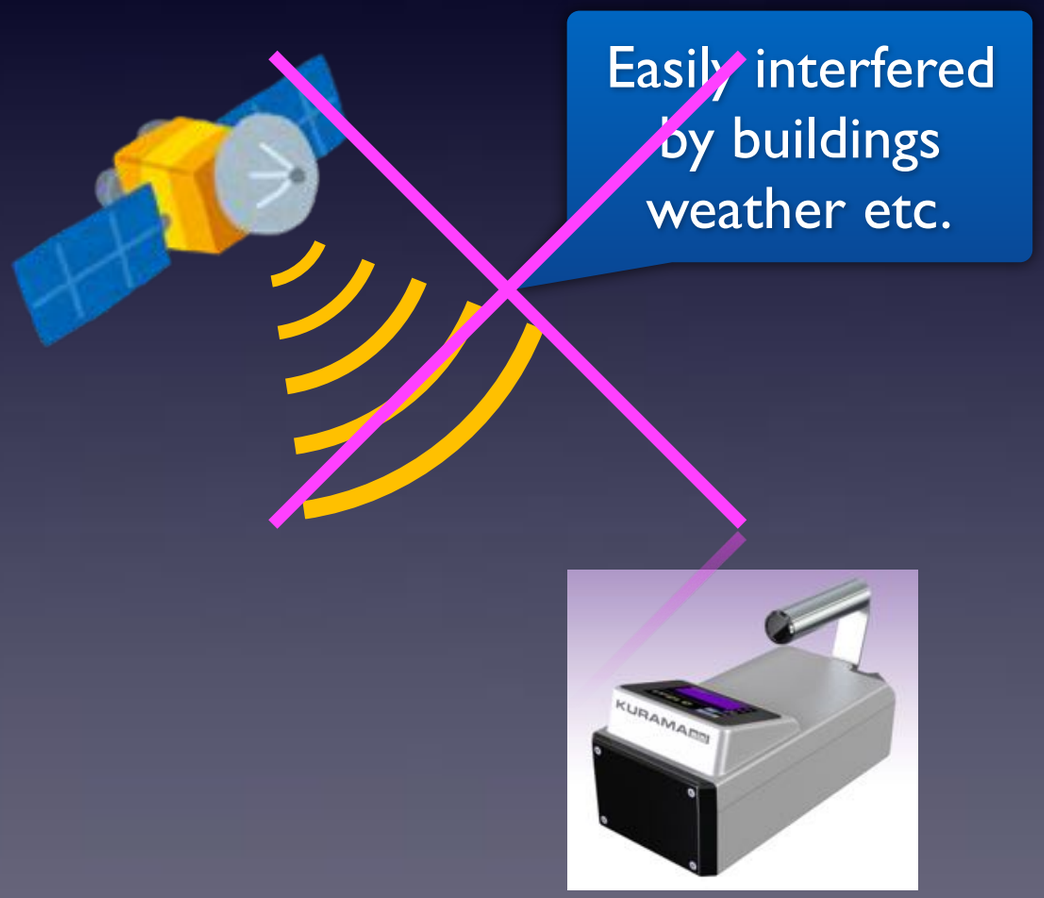
Mobile Network



Challenges

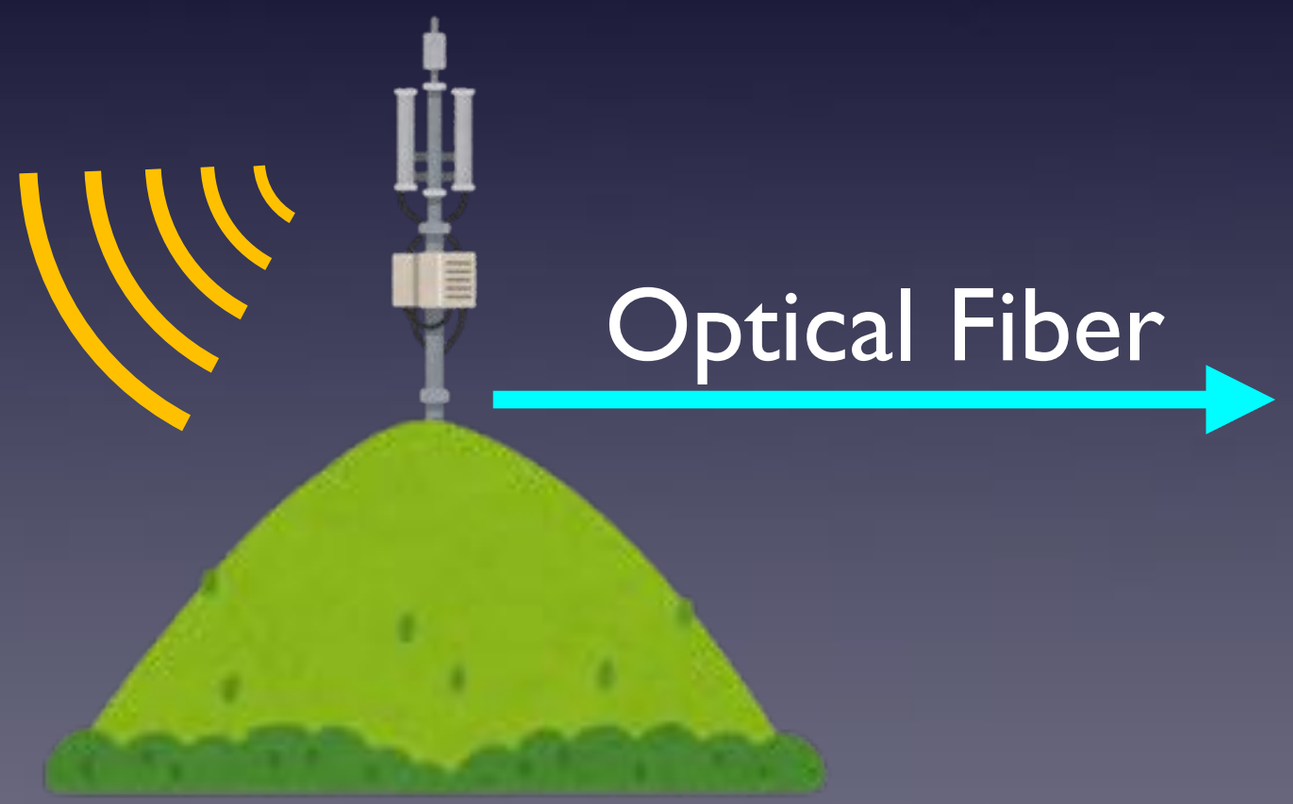
More reliable communication under emergency

Satellite Channel



KURAMA-mini

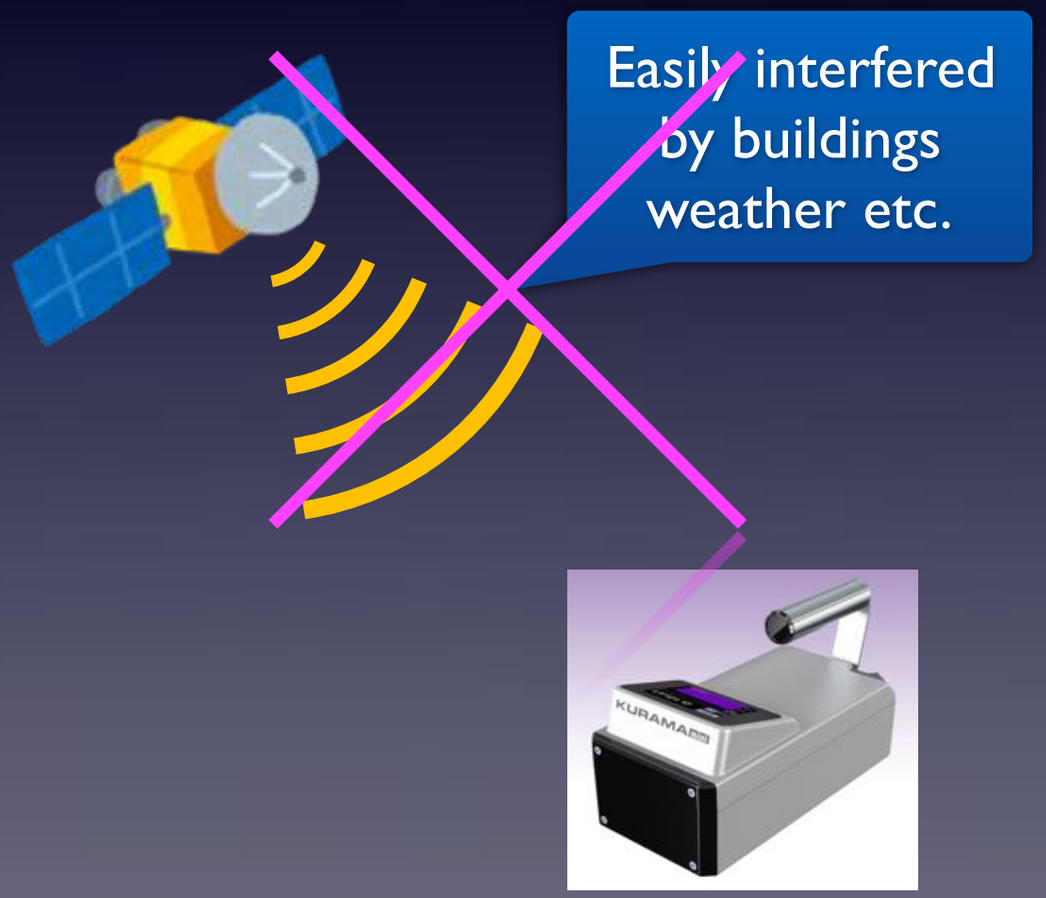
Mobile Network



Challenges

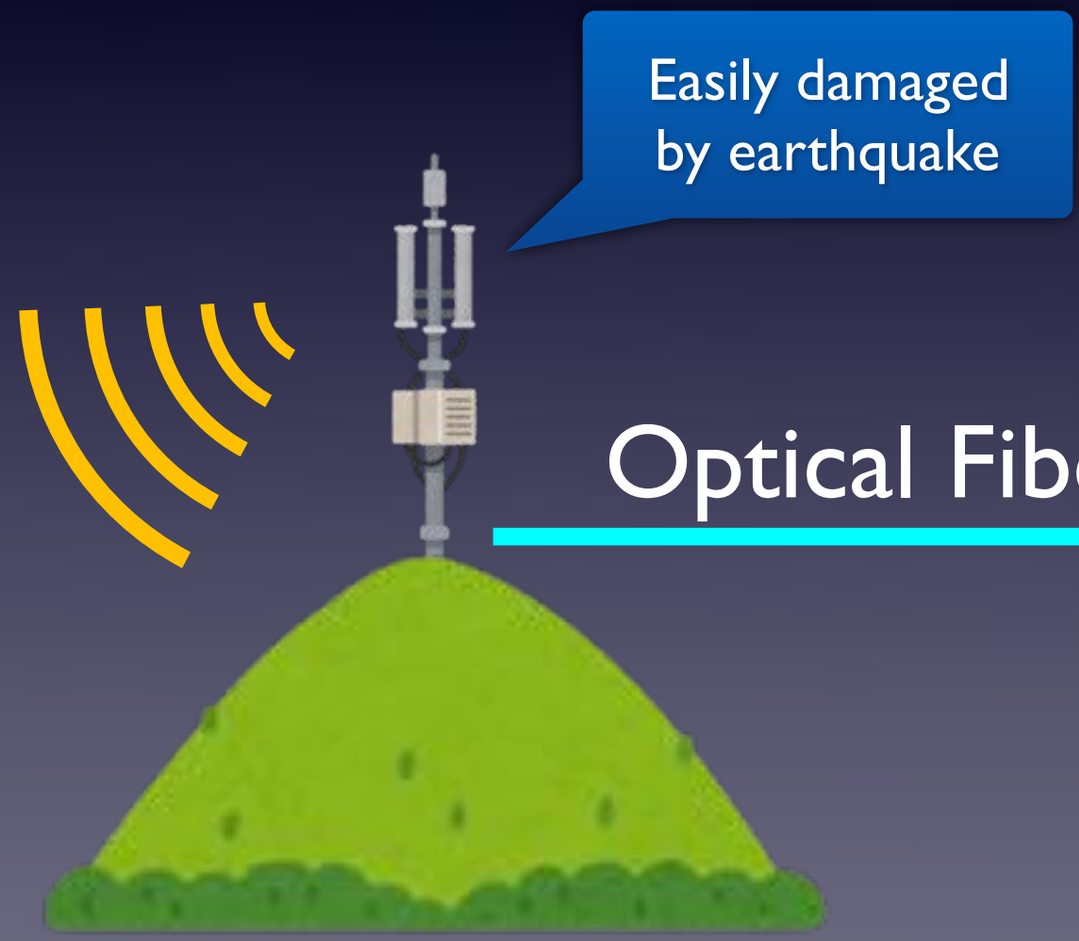
More reliable communication under emergency

Satellite Channel



KURAMA-mini

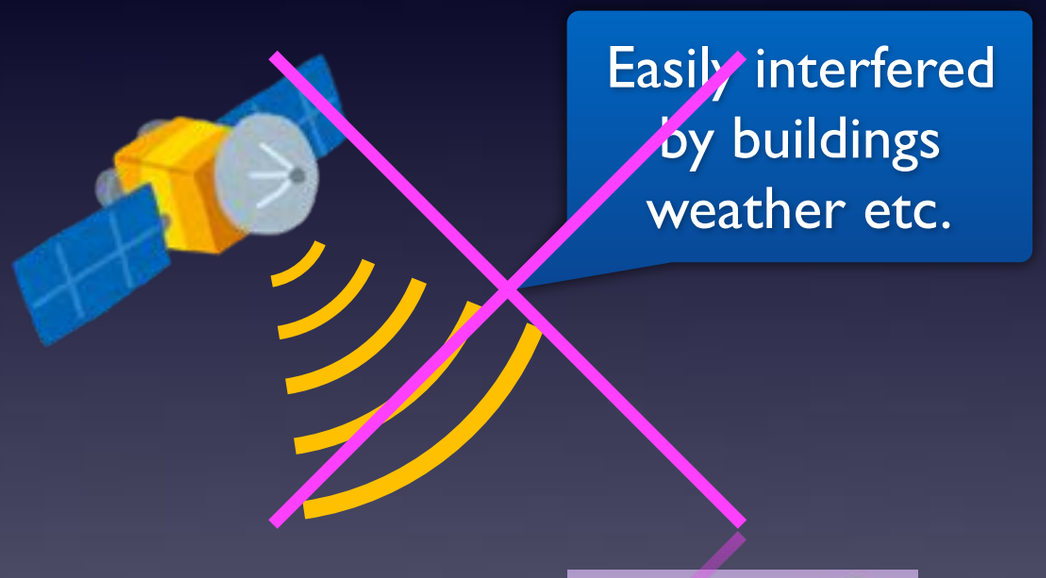
Mobile Network



Challenges

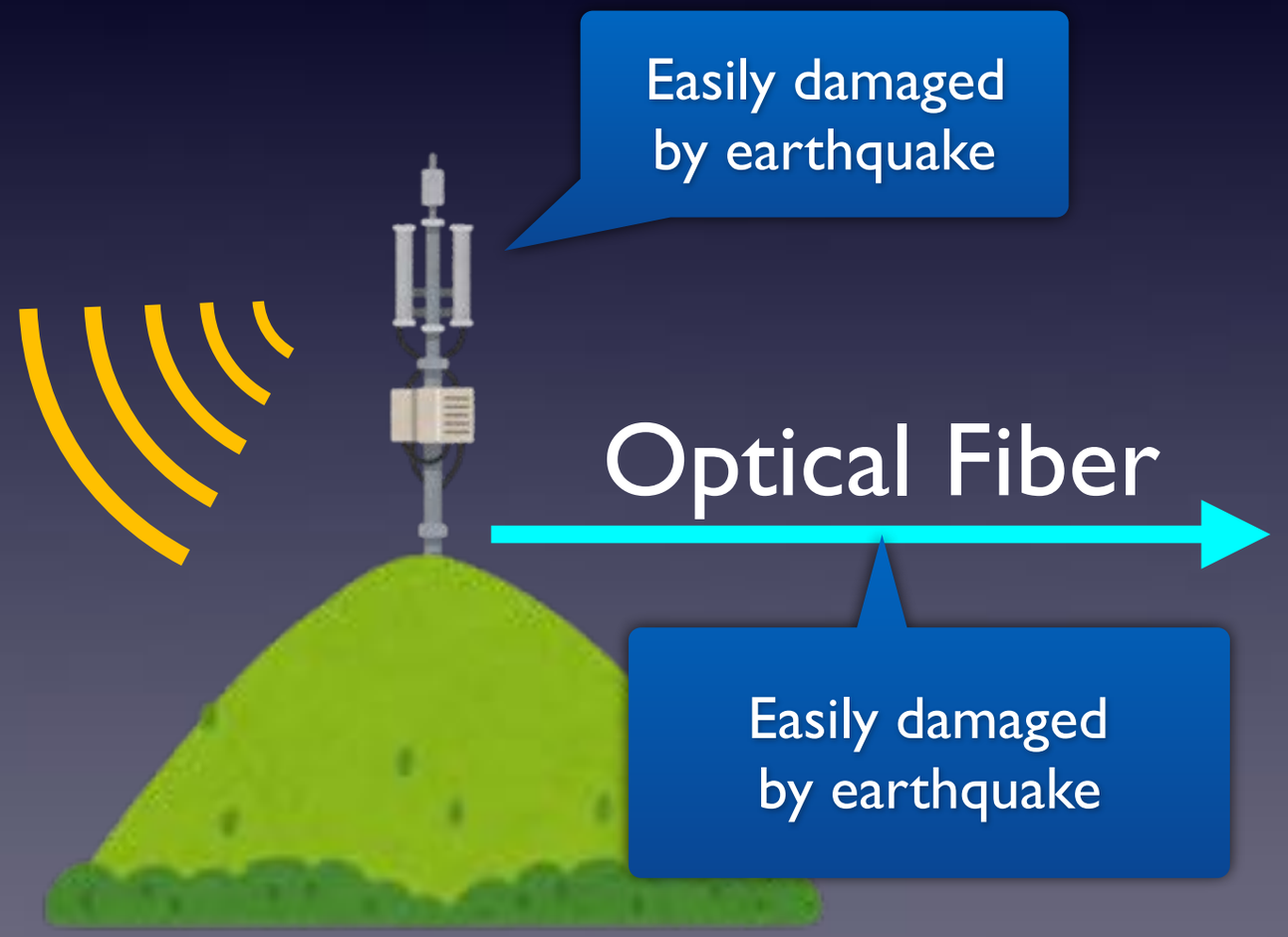
More reliable communication under emergency

Satellite Channel



KURAMA-mini

Mobile Network



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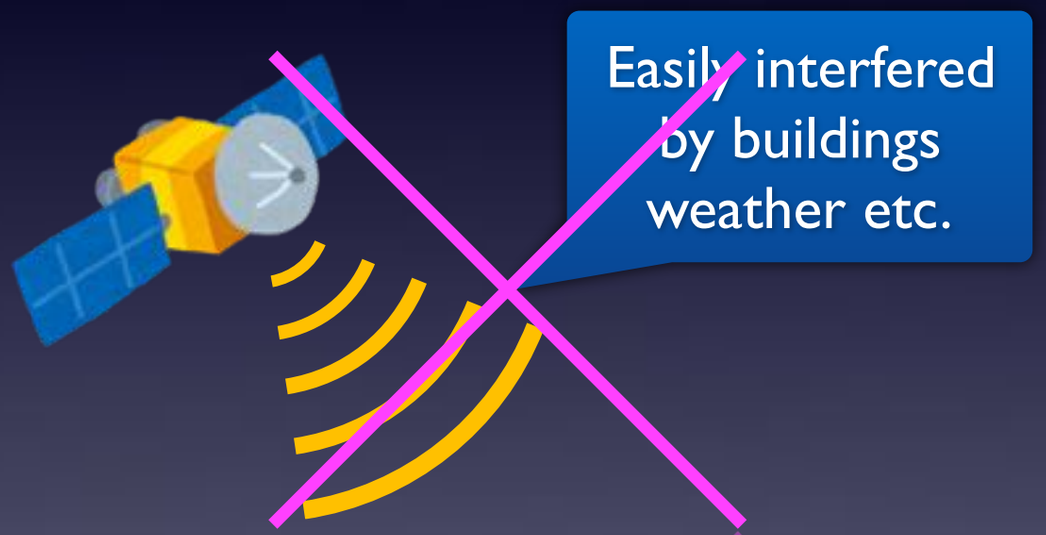
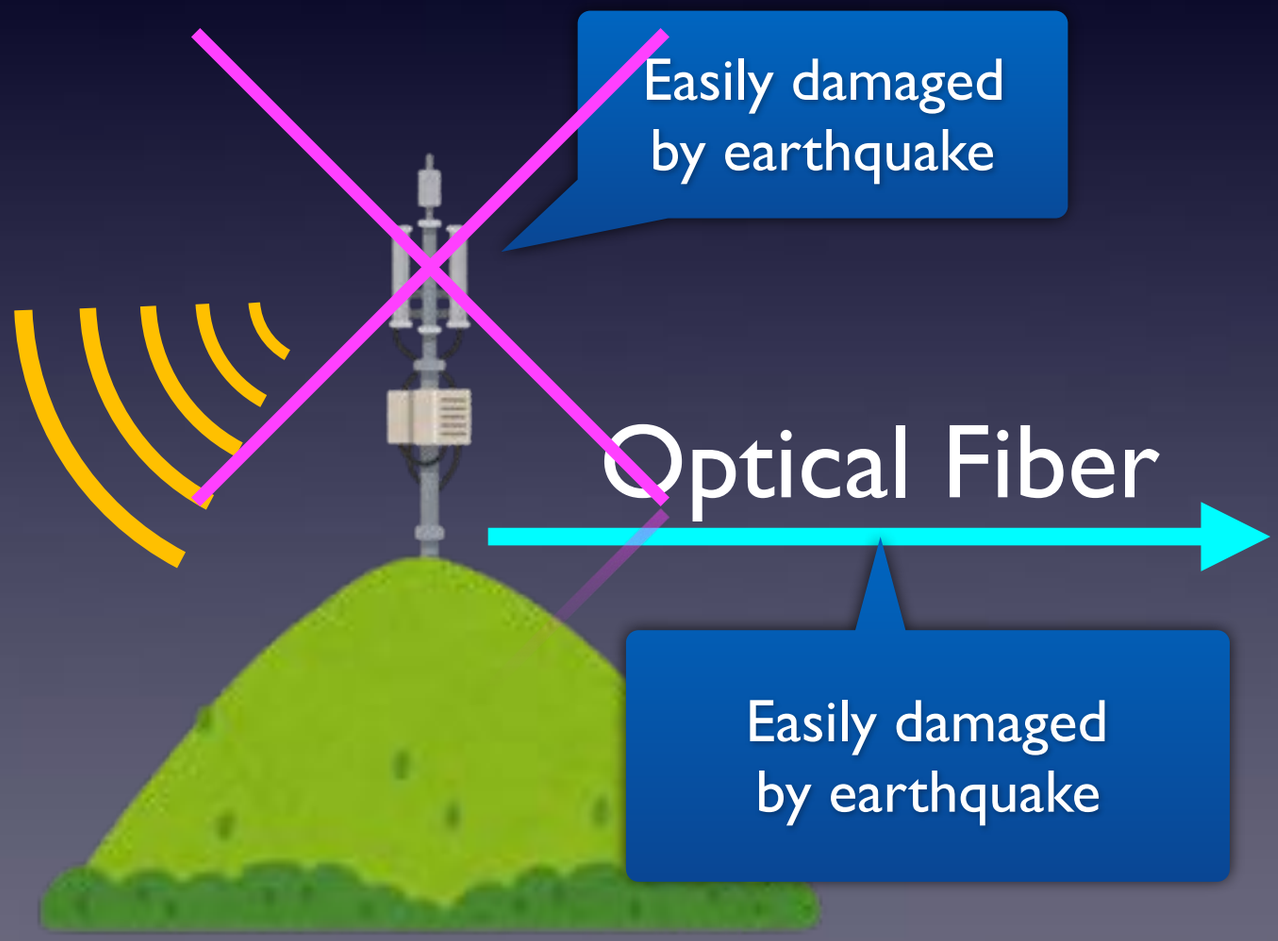


KURAMA-mini

Mobile Network



LPWA

Networks for IoT in field

	ISM		LTE (Release 13)	
	SIGFOX	LoRaWAN	Cat. M1	Cat. NB1
Up/Down	0.1 k	3 k	0.8 M/0.8 M	26 k/62 k
Band width	100 Hz	125 kHz	1.4 MHz	200 kHz
Power	20 mW	20 mW	20/23 dBm	23 dBm

LPWA

Networks for IoT in field

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Band width	100 Hz	125 kHz	1.4 MHz	200 kHz
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Handover/
Autonomous network

Summary

- KURAMA-II has been extensively used for radiation monitoring in Japan
- Applications are extending
  (e.g. prompt estimation of soil contamination, survey units for emergency response)

Acknowledgements

Fukushima Pref. : Mr. Koyama, Dr. Mizuno, Mr. Abe, Mr. Kojima, Mr. Hada,
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Dr. Ando
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Hamamatsu : Mr. Nakamura
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Shinjoban Kotsu : Mr. Kawakami, Mr. Monma, Mr. Suzuki
Aizunoriaijidosha : Mr. Sugihara, Mr. Sato
Matsushimaya Inn : Mr. & Mrs. Takahashi

Matsushimaya Inn at Fukushima city

Devoted support for our activities
regardless of their severe situation by earthquake
and nuclear accident

KURAMA-II on Bike

Visit Matsushimaya-inn, Fukushima.
Enjoy good hot spring, nice food, and KURAMA-II.