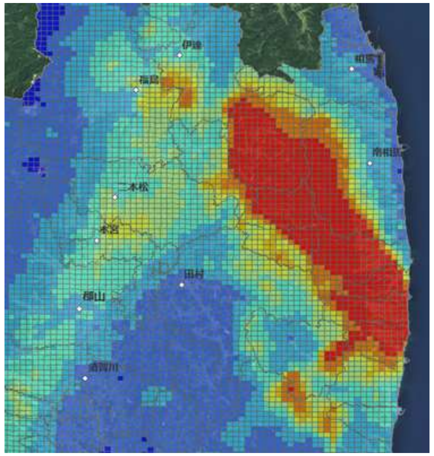
EAN 17th Workshop on ALARA in Emergency Exposure Situations
15-17 May 2017, Lisbon Portugal

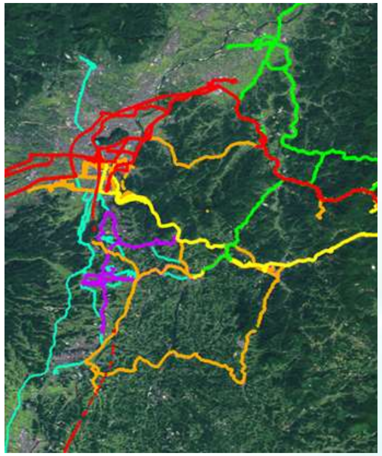
The use of electronic dosimeter for individual exposure assessment and management after a nuclear accident : The example of the D-Shuttle in the Fukushima Prefecture

Research Institute of Science for Safety and Sustainability (RISS)

National Institute of Advanced Industrial Science and Technology (AIST),

Wataru Naito, Motoki Uesaka





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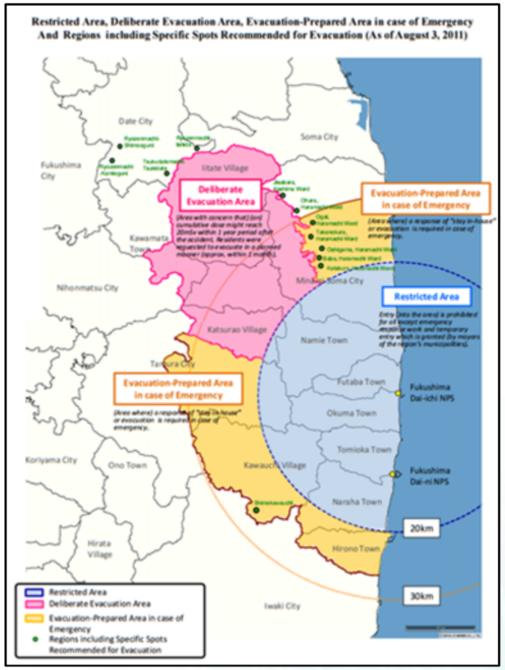
Decisions regarding the decontamination and evacuation areas have been determined on the basis of "air dose rate" with a simple equation with conservative assumptions.

The government has designed the **decontamination works** and the **criteria for the evacuation and lifting the evacuation orders** on the basis of **additional individual external dose** estimates using the simple model proposed by the Ministry of Environment.



(Air dose rate 0.23 µSv/h − Natural radiation dose rate from the earth 0.04 µSv/h) × Shielding effect (8+16×0.4) × 365 days / 1,000 = Additional dose 1 mSV/y

- Natural radiation dose rate from the earth: National average
- Shielding effect: Assuming spending 8 hours outside and 16 hours inside a wooden house (radiation is reduced to 40% due to shielding) every day
- 1,000: 1,000µSv=1mSv
- Additional dose: Annual dose

The **long-term goal** under the Decontamination policy is to reduce **additional annual exposure to 1 mSv**

An annual exposure of 1 mSv (air dose rate of 0.23 µSv/h) has been recognized as a 'safe' level by the public.

It is important to correctly understand and assess realistic individual external doses.

There are gaps between individual external doses obtained by personal dosimeters and the individual doses estimated by the simple model.

Complicated dose quantities and units for radiation protection caused confusion among the general public and even among experts and regulators.

Monitoring post

Real-time dosimeter

Airborne radiation monitoring

http://jolisfukyu.tokai-sc.jaea.go.jp/fukyu/mirai-en/2012/1_6.html

Glass Badge Dosimeter

http://www.minpo.jp/pub/topics/jishin2011/2011/07/post_1501.html

Accurate information on individual external doses is needed by the government policymakers, by people providing health care and radiation dose mitigation advice, and especially by affected citizens.

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Study Goal and Objectives

The primary goal of our study is to establish a sound and pragmatic approach to assess and manage the external exposure of individuals in the affected areas in Fukushima.

- Understand the realistic external exposure of individuals in the affected areas in Fukushima
- Elucidate the relationships between individual external doses with activity patterns and ambient doses (based on airborne monitoring data)
- Establish a pragmatic estimation tool to assess and manage the individual external doses

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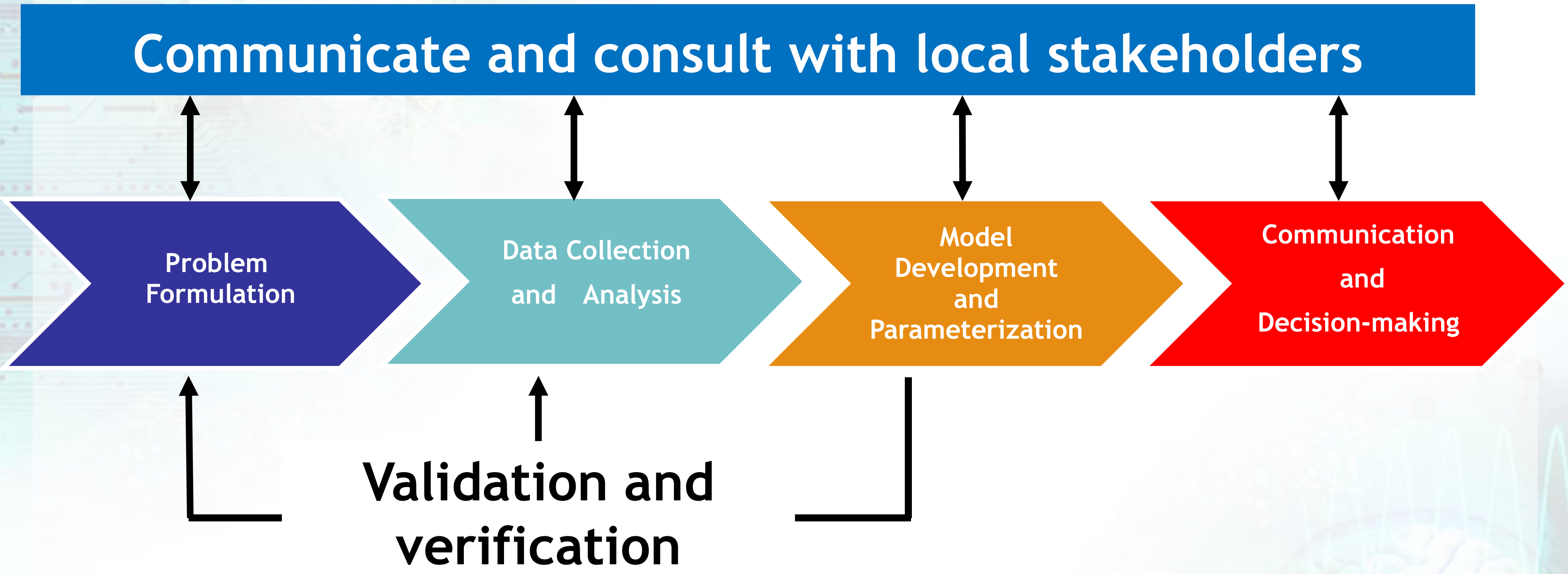
Framework of our individual external dose assessment research



Communicate with many stakeholders (e.g., local residents, government and municipality) throughout all stages of the study

Support of local residents is essential for the data collection stage

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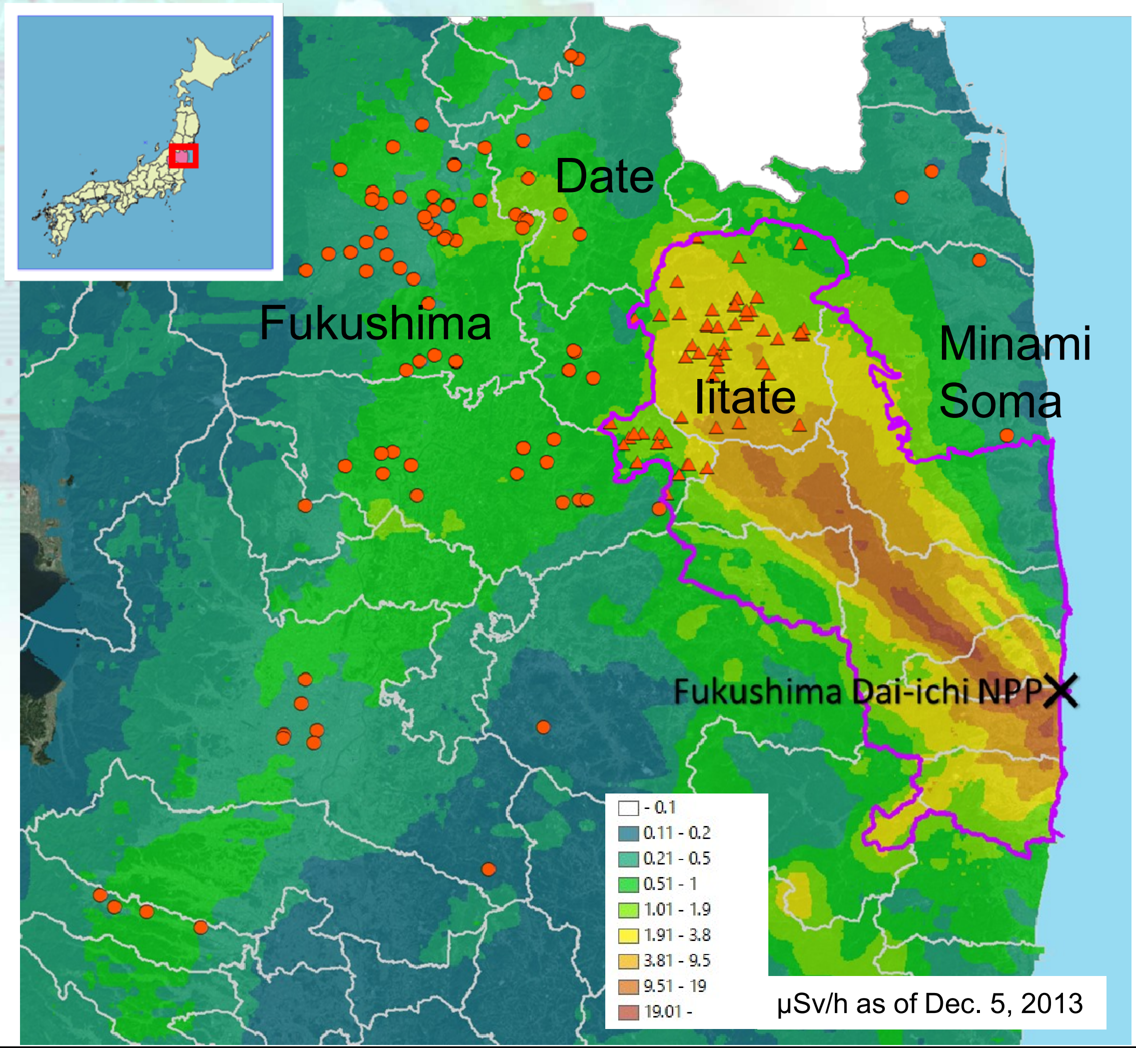
Study Area



● Participants' residence
▲ Former residence in evacuation zone

— Evacuation zone (2015)

Number of participants (residents in evacuation zone)

2013: 50 (0)
2014: 96 (16)
2015: 76 (55)
2016: 15 (15)

To date, approximately 250 Fukushima residents participated in our study

This study was approved by the Committee for Ergonomic Experiments in the AIST.
Written informed consents were obtained from all participants prior to conducting the study.

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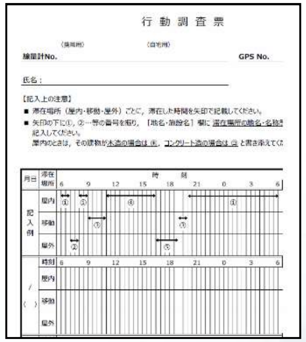
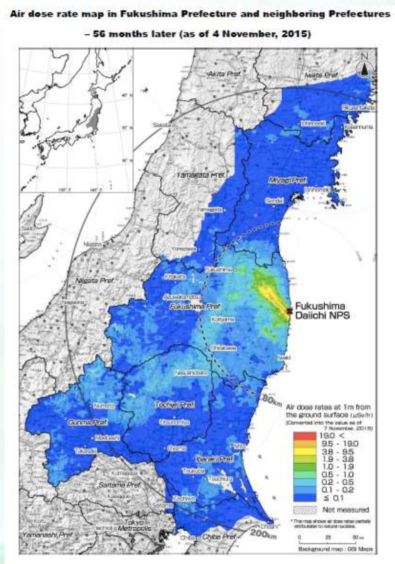
What kinds of data were collected ?

Data collection periods :
approximately 7 – 14 days (Sep. 2013 – May 2016)



- Personal external exposure
  → D-shuttle (hourly dose, μSv/h)

- Location and activity-patterns of individuals
  → GPS receiver and time-activity diary

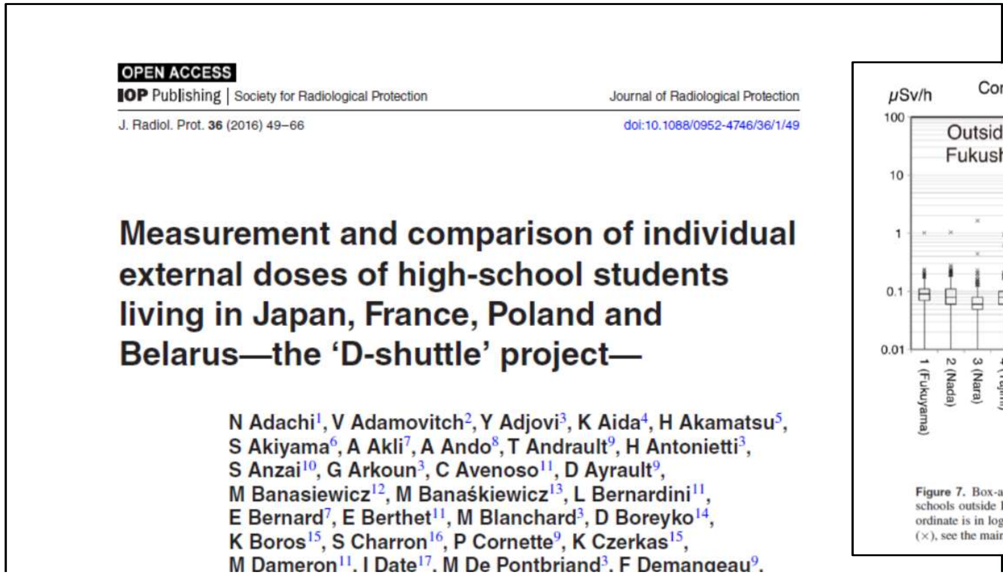


- Air dose rate
  → Airborne monitoring conducted by
    Nuclear Regulation Authority, Japan

A Well-Designed Personal Dosimeter - D-shuttle-

- Developed by AIST, and produced by Chiyoda Technol. Inc.
  - ✓ Long battery life: 1 year
  - ✓ Monthly, Daily and Hourly dose trend
  - ✓ Light and compact size
  - ✓ Designed to detect gamma-ray

- D-shuttle has been used for several municipalities in Fukushima



OPEN ACCESS
IOP Publishing | Society for Radiological Protection
Journal of Radiological Protection
J. Radiol. Prot. 36 (2016) 49–66
doi:10.1088/0952-4746/36/1/49

Measurement and comparison of individual external doses of high-school students living in Japan, France, Poland and Belarus—the 'D-shuttle' project—

N Adachi[1], V Adamovitch[2], Y Adjovi[3], K Aida[4], H Akamatsu[5], S Akiyama[6], A Akli[7], A Ando[8], T Andrault[9], H Antonietti[3], S Anzai[10], G Arkoun[3], C Avenoso[11], D Ayrault[9], M Banasiewicz[12], M Banaśkiewicz[13], L Bernardini[11], E Bernard[7], E Berthet[11], M Blanchard[3], D Boreyko[14], K Boros[15], S Charron[16], P Cornette[9], K Czerkas[15], M Dameron[11], I Date[17], M De Pontbriand[3], F Demangeau[9],

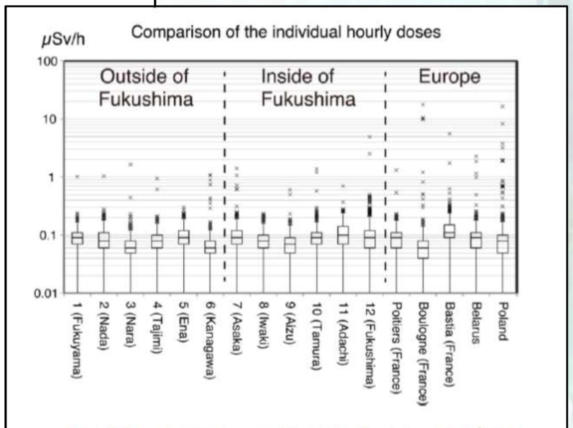
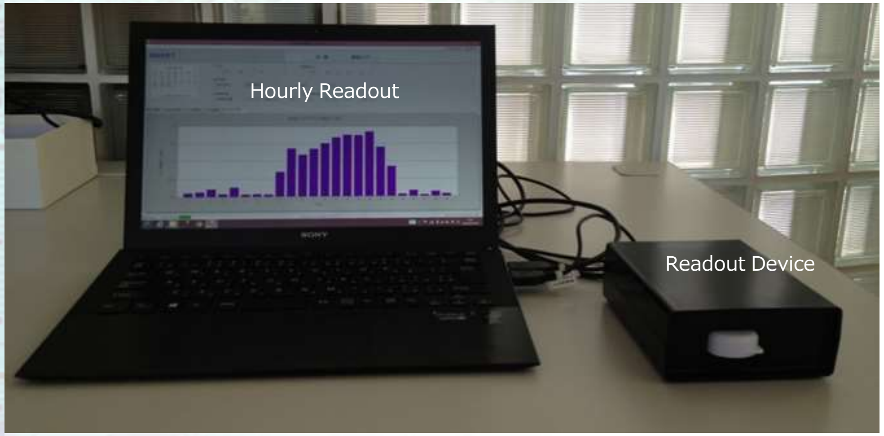
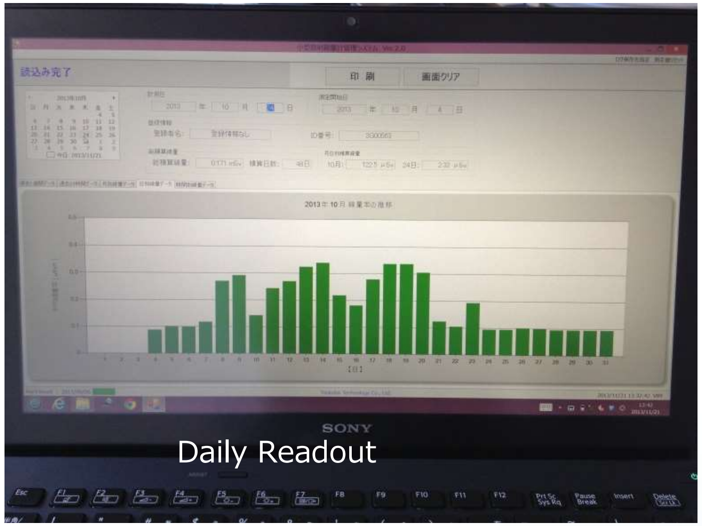
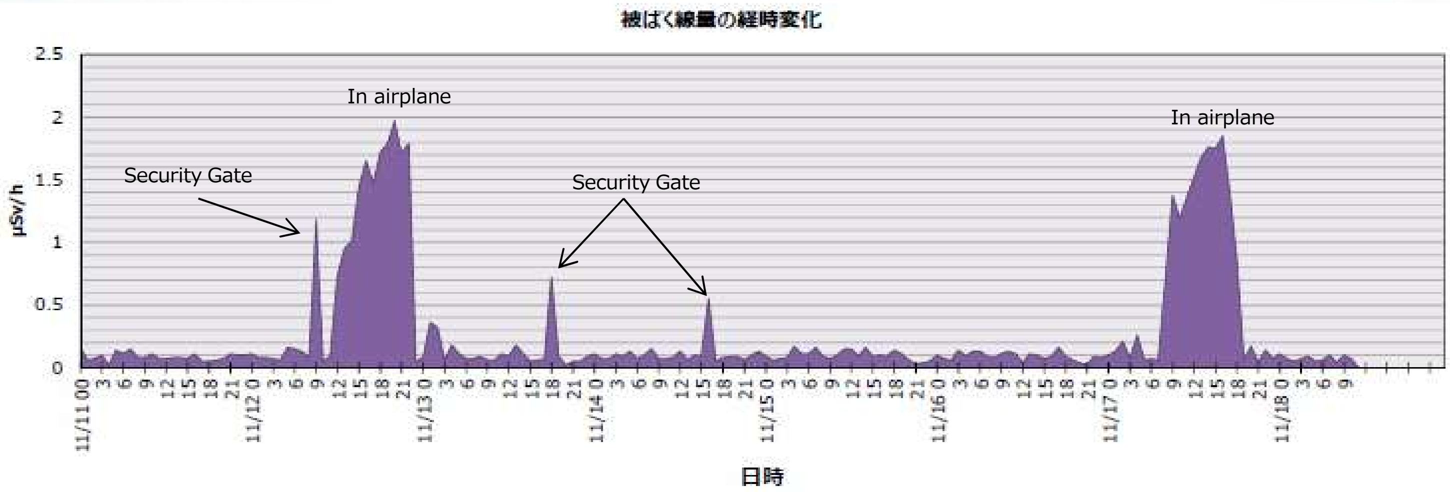


Figure 7. Box-and-whisker diagrams of the individual hourly dose (μSv h^{-1}) for 6 schools outside Fukushima, 6 schools in Fukushima, and five European regions. The ordinate is in logarithmic scale. For the definitions of the boxes, whiskers and outliers (×), see the main text.

Readout from D-shuttle



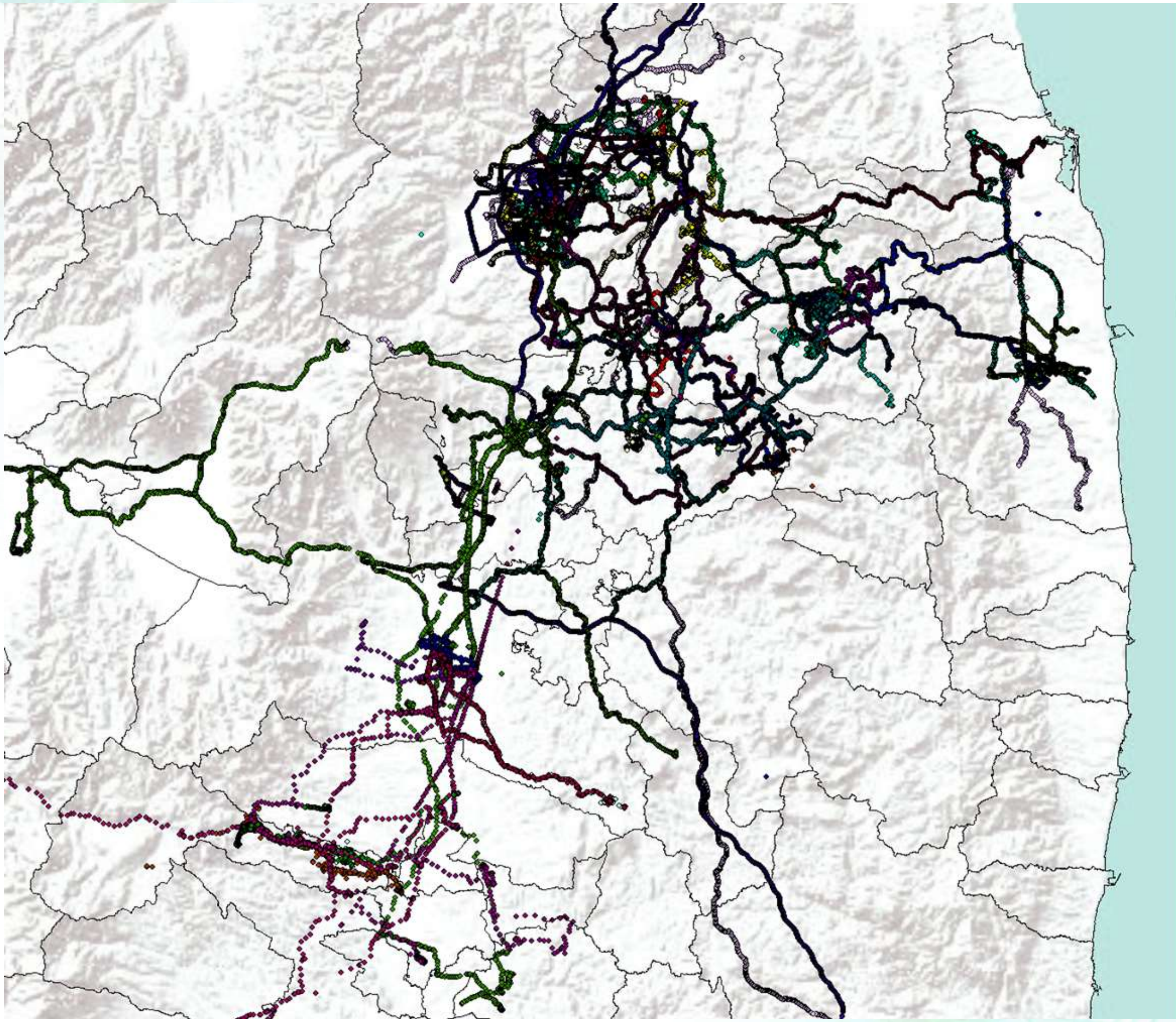




Examples of Readout from GPS

i-gotU GT-600（MobileAction Technology, Inc.）

Set to record latitude and longitude every 5 seconds



Integration of individual external dose, air dose and time-activity patterns using GPS/GIS

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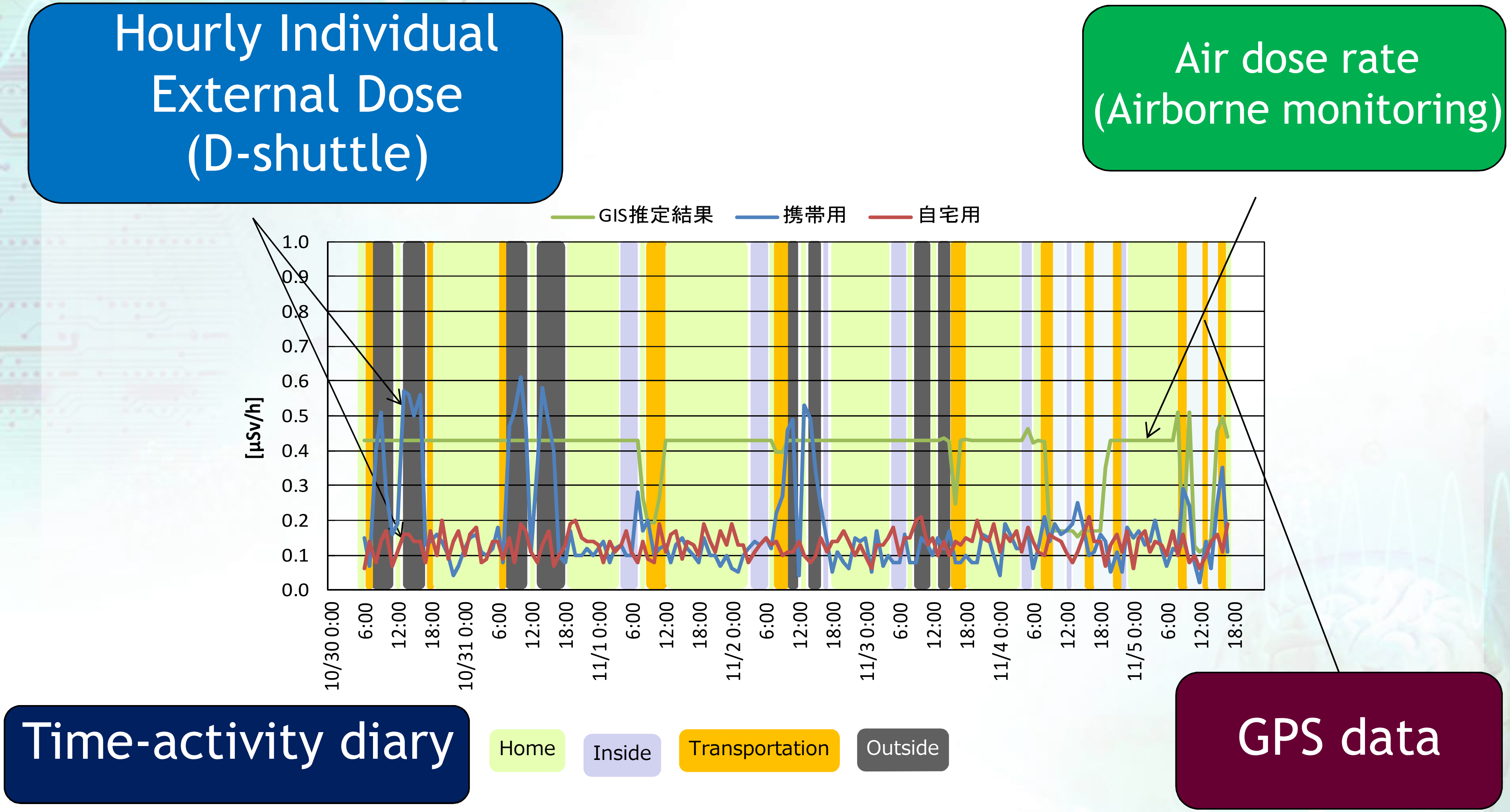
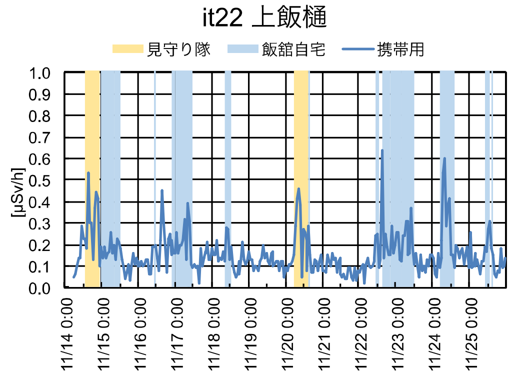
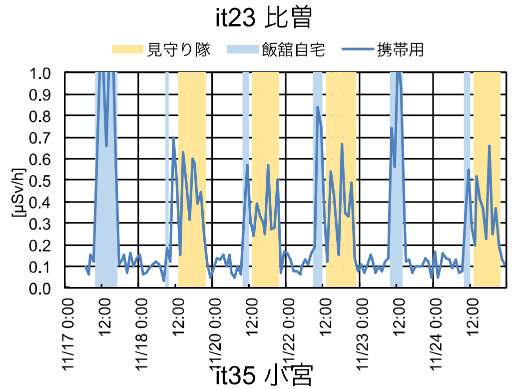
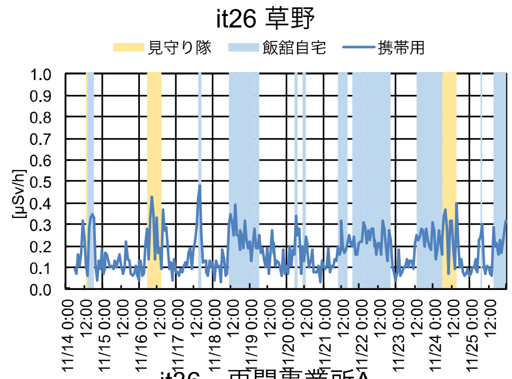


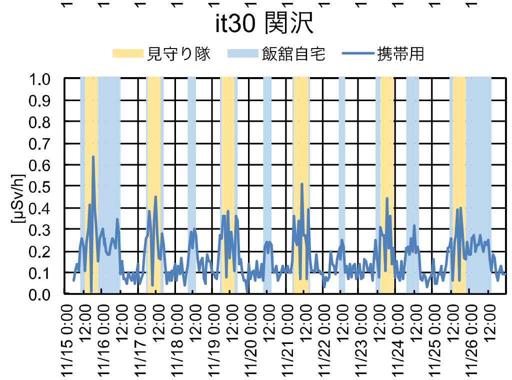
Spatial-temporal radiation exposure assessment using D-Shuttle with GPS/GIS technologies allowed for identification of peak exposure locations/times.

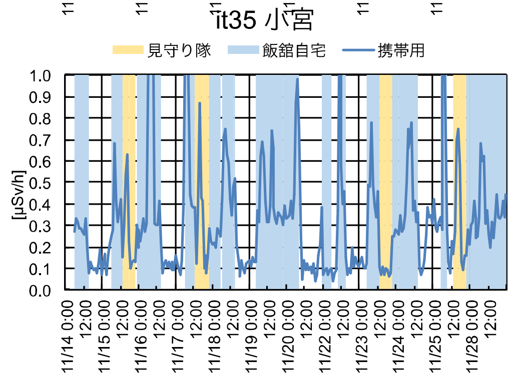
Examples of individual external dose profiles obtained by D-shuttle in Iitate village

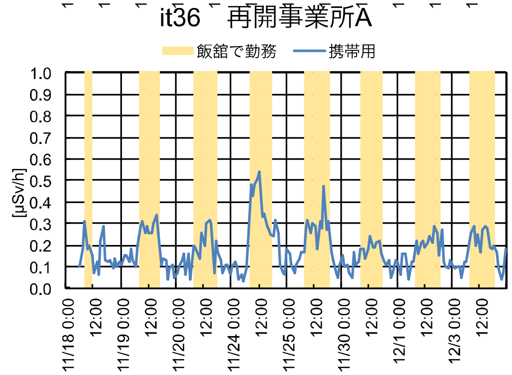


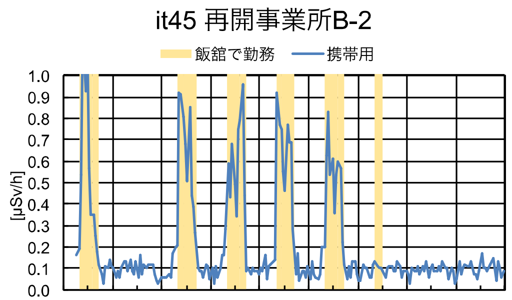


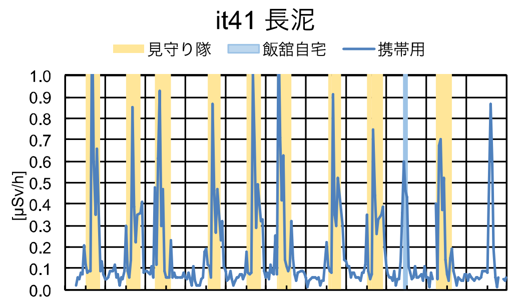












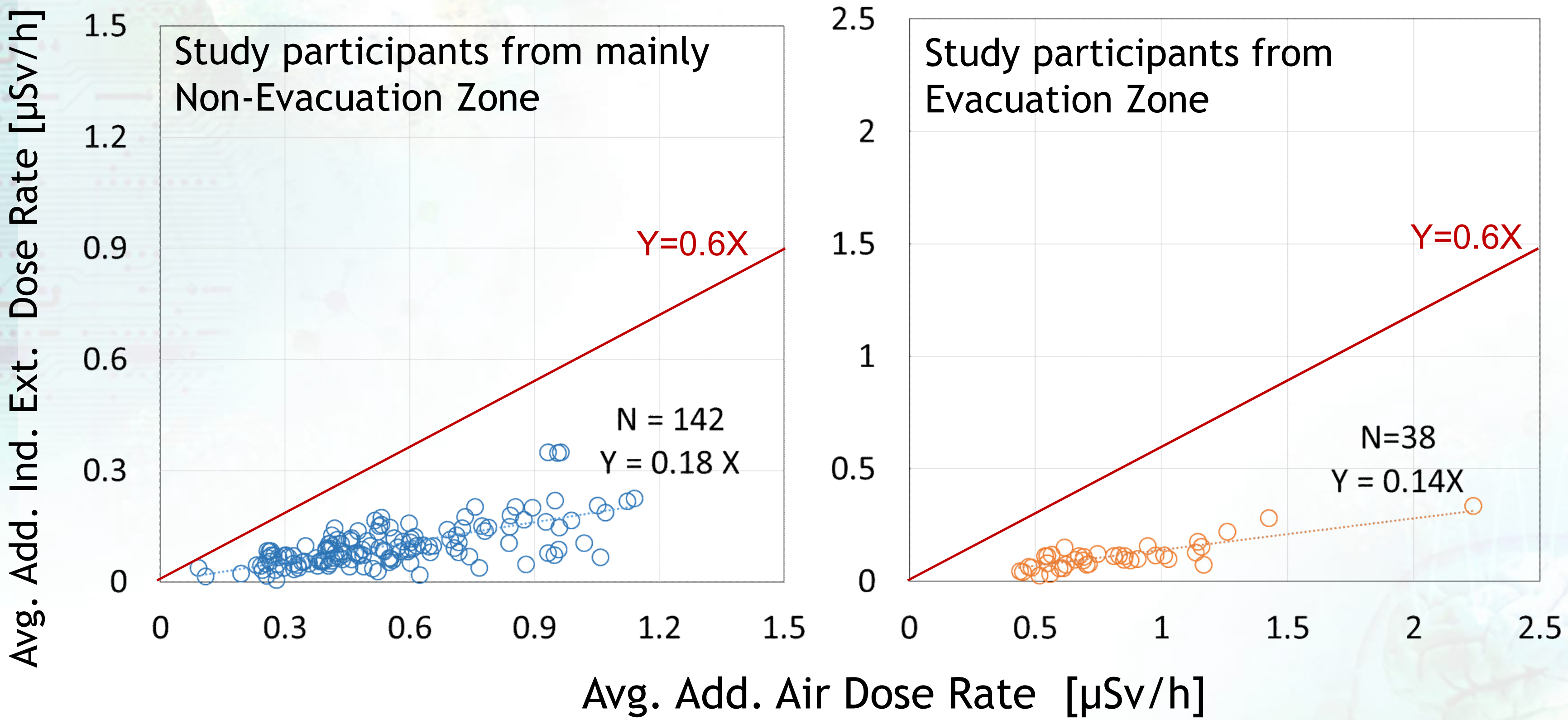
Horizontal axis : date

Vertical axis : dose [µSv/h]

- ✓ External dose profiles vary depending on activity patterns and locations of individuals.
- ✓ D-shuttle provides reliable information for residents to understand the radiation situation in their daily life.

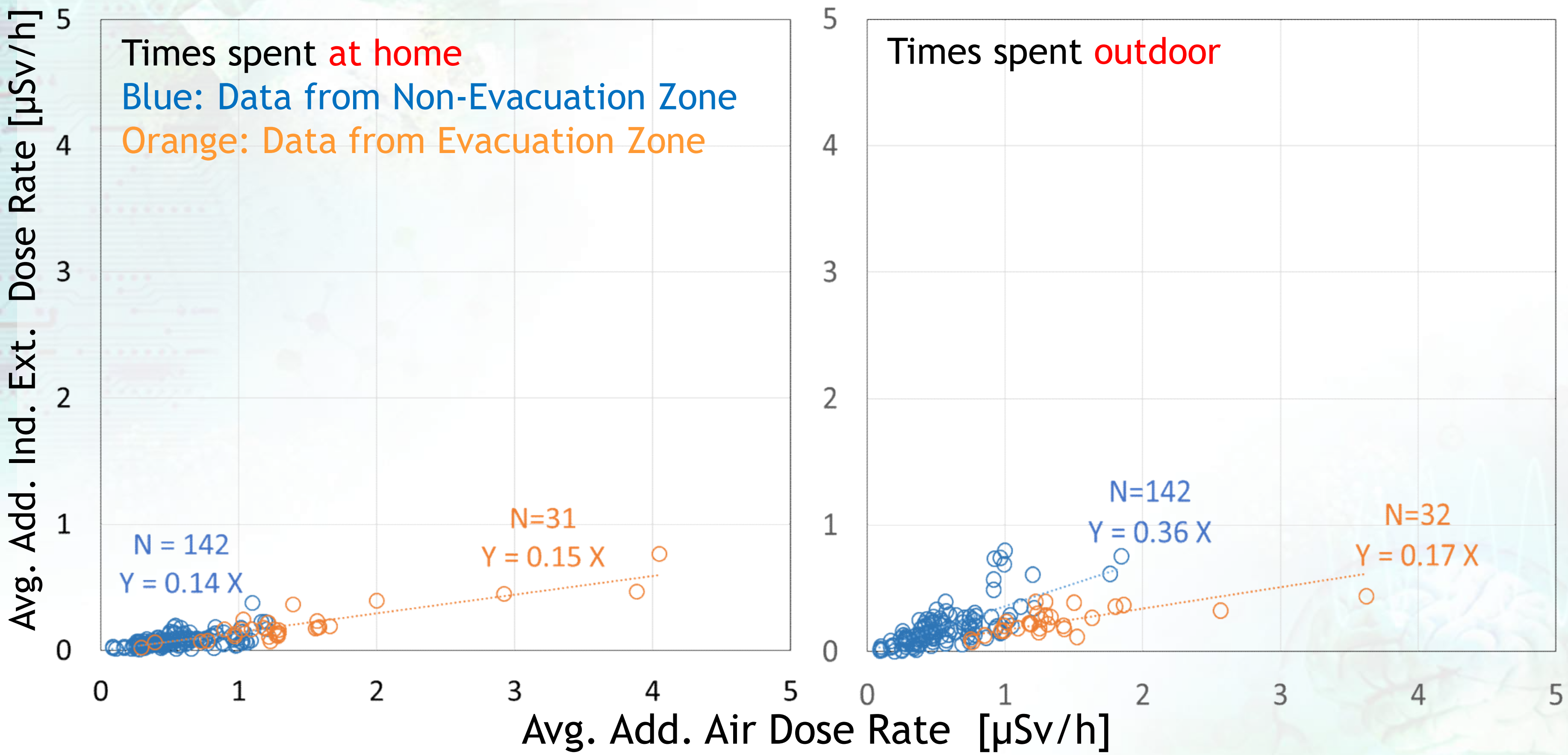
Relationship between individual external dose and ambient dose

Expressed as hourly dose on average of times spent during all study periods



Additional individual external doses obtained by D-shuttle were 0.18 and 0.14 times on average of the corresponding cumulative air dose based on the airborne monitoring for non-evacuation zone and evacuation zone, respectively.

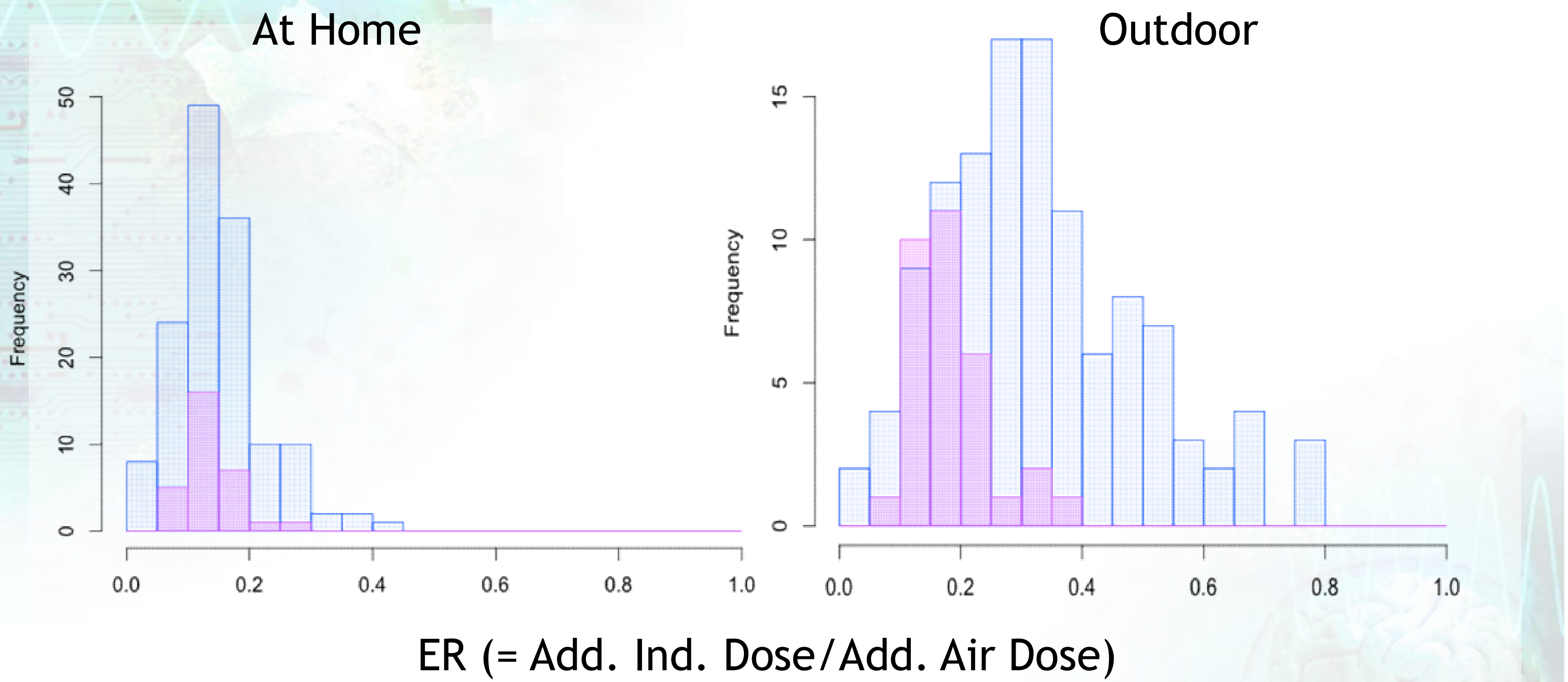
Relationship between individual external dose and ambient dose



Add. Ind. Ext. doses obtained by D-shuttle were **0.14 and 0.15** times on average of the corresponding cumulative amb. doses for non-evacuation zone and evacuation zone during times spent at home, respectively.

Add. Ind. Ext. doses obtained by D-shuttle were **0.36 and 0.17** times on average of the corresponding cumulative amb. doses for non-evacuation zone and evacuation zone during times spent at outdoor, respectively.

Distributions of Exposure Ratios (ER) for times spent at home and outdoor



Purple : Data from Evacuation Zone (i.e., Iitate village) from Naito et al. (Accepted)
Blue : Data from Non-Evacuation Zone from Naito et al. 2016

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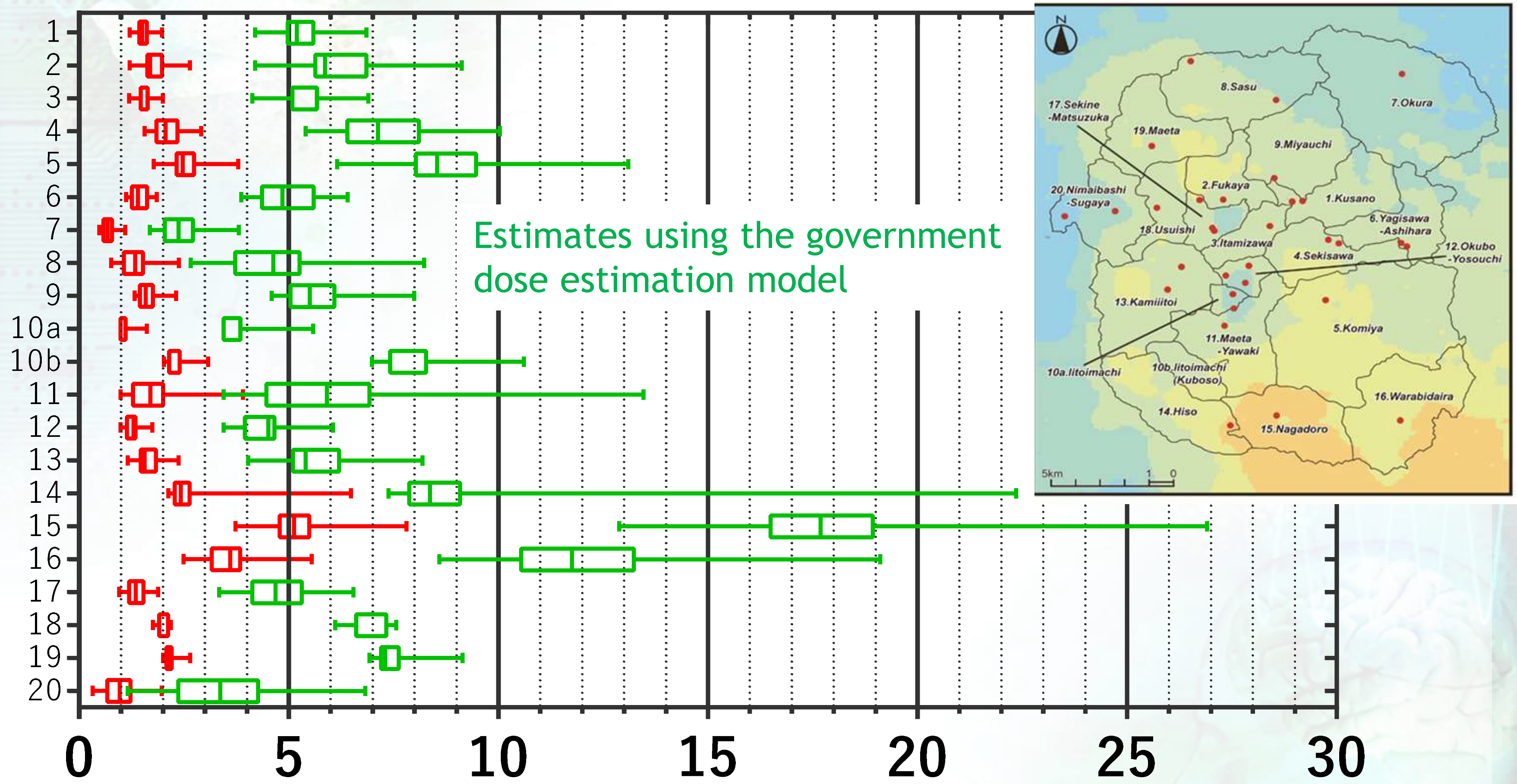
Distribution of Estimated Additional Individual External Doses in different administrative districts of the Iitate

Ref. Naito et al. (accepted)

Assuming people stay 16 hours indoors and 8 hours outdoors



Estimated Additional Annual Individual External Dose [mSv] as of April 1, 2017

The estimates of individual external doses based on the result from our study were about ¼ of the estimates calculated by the government dose estimation model.

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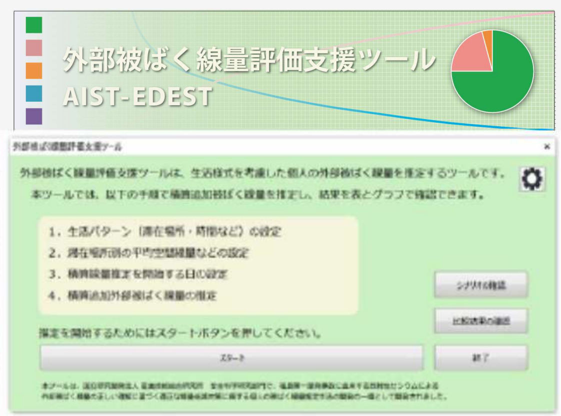
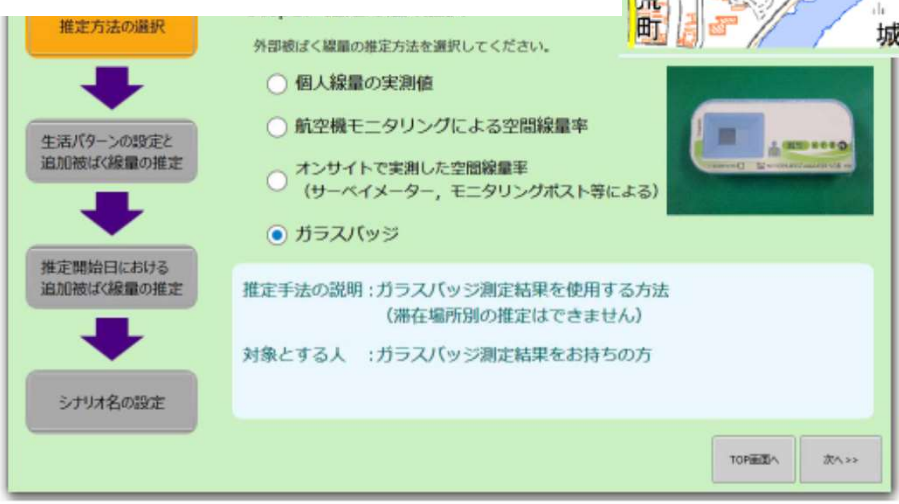
A tool to support for estimating realistic individual external dose in Fukushima

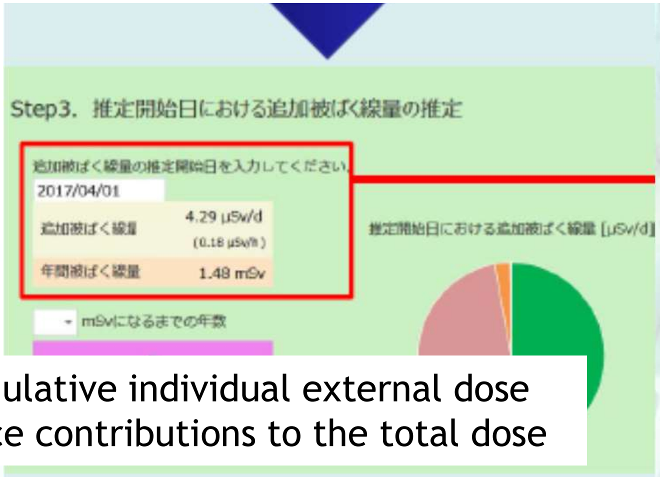
Given the ambient dose rates and activity-patterns, what is my individual external dose in future?
What is the reduction goal to be able to achieve individual external dose of XX mSv considering activity-pattern?



Select a estimation method



Select your time-activity pattern
Input ambient dose or personal dose of each location or activity



Estimate cumulative individual external dose
Identify source contributions to the total dose

https://www.aist-riss.jp/softwares/41418/

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Interview with study participants of Iitate

- Do you have any radiation dose level that you feel secure ? (What are the reasons?)
  - 1 mSv/yr （e.g., Because the government say so, situation in non-evacuation areas)
  - 2 mSv, but considering my grandchild, probably 1 mSv/yr
  - I feel secure with the current levels (2-3 mSv）
  - I don’ care
  - 5 mSv (e.g., because the realistic goal of the village)

- What kind of radiation information do you need for returning your home in Iitate ?
  - Future radiation dose after the return to the village and potential effects
  - Personal dose information, not monitoring post in the vicinity
  - Information that can be used to explain my children and grandchildren to visit Iitate at ease
  - How long I can stay outdoor
  - Information to judge what information is correct

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Interview with study participants of Iitate

- What do you think of your personal dose level (obtained by D-shuttle)?
    - Higher than expected. I want to return, but it seems long way to achieve 1mSv-yr, I want to request more decontamination works
    - Lower than expected, but 2-3 times higher than Fukushima city (at temporary house)
    - Lower than expected (When I stayed in the village, I tried to stay inside my house)
    - It’s my first time to see time trend of my dose, I feel secure
    - I understand differences between dose levels during times spent indoor and outdoor, overall it doesn't affect my way of living in Iitate.
    - I don’t know (it is difficult to judge) because no information to compare with

- Do you feel secure when you see your own personal dose data?
    - Measured data will surely help to understand and feel secure about radiation exposure situation around my house, but I haven’t decided to return to my home.
    - I don’t know because I don’t have any criteria for safety.
    - I was relieved to know locations where higher radiation levels were measured.
    - I have to accept the current level because I need to return to my home in Iitate anyway

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Interview with study participants of Iitate

- Is the your radiation condition an important element for your decision to return to your home in Iitate after lifting the evacuation order?
  - I used to worry about the radiation situation in Iitate, but no worry now.
  - I feel secure after my doctor said the radiation level around my home is no problem.
  - Yes, 1 mSv is an important element for my decision to return to Iitate (considering other family members)

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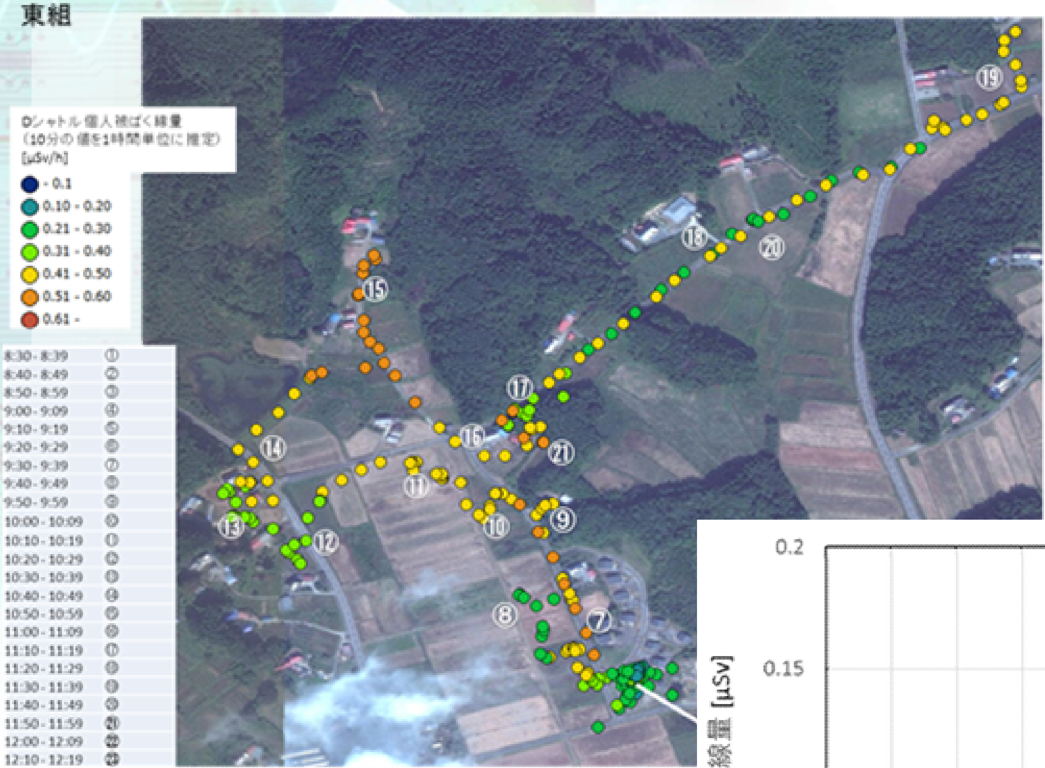
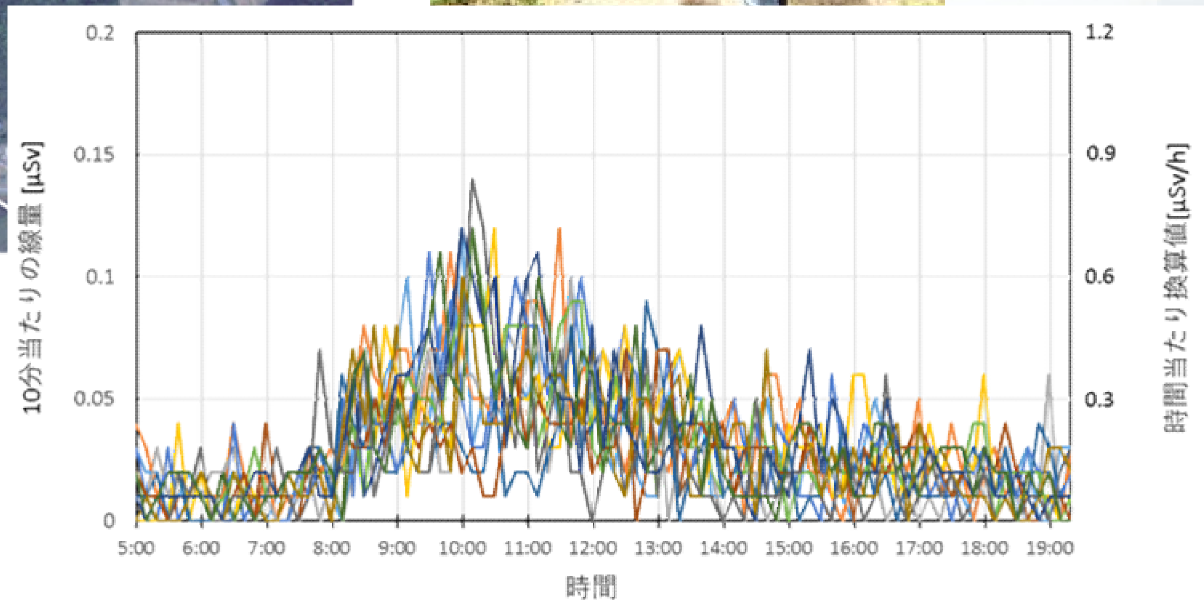
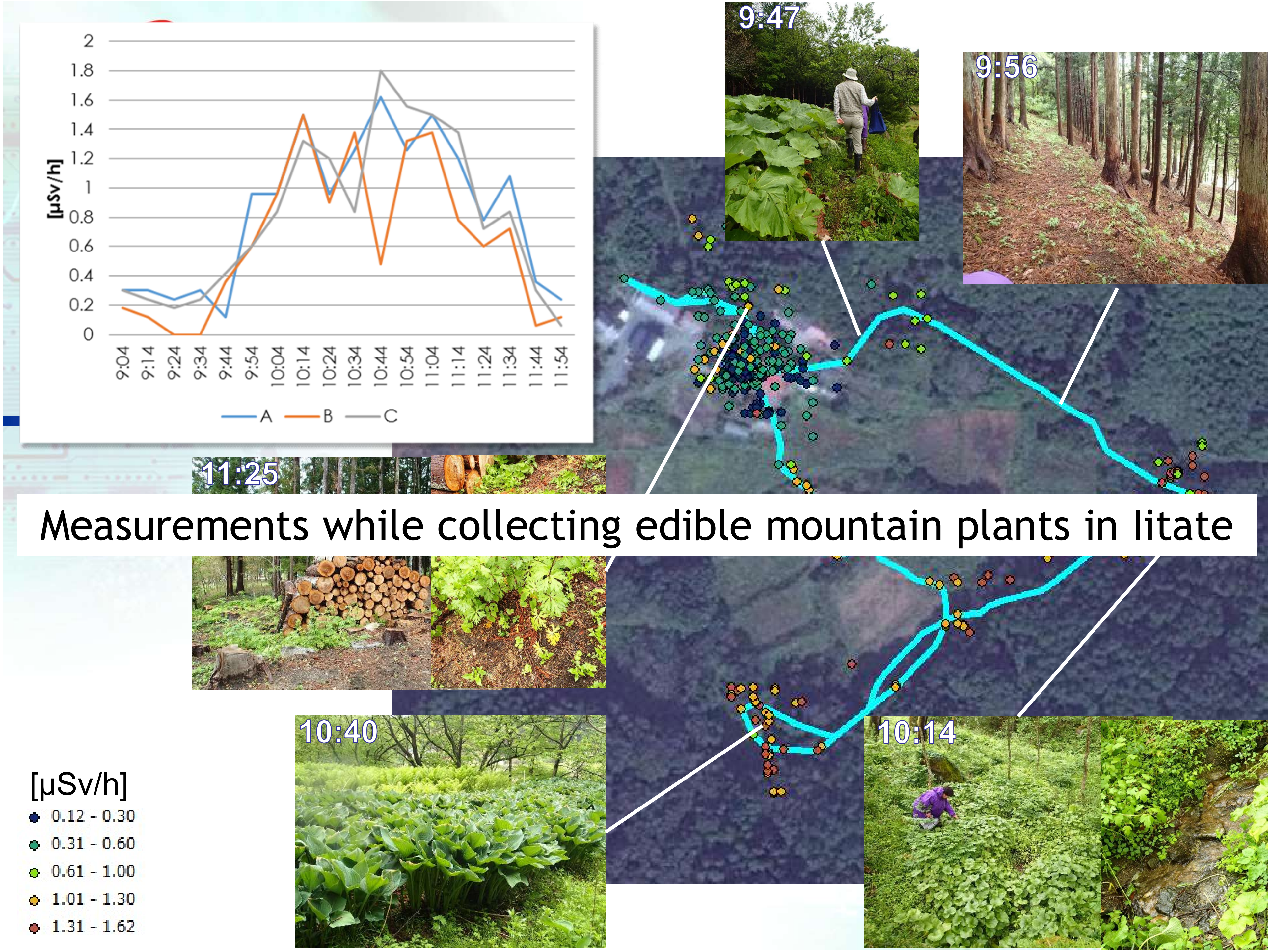
Other D-shuttle Examples: Measuring and sharing radiological situations with local people in Iitate





Measurements while collecting edible mountain plants in Iitate



Lessons Learned through our study (1)

- The "Long-term" goal of 1 mSv (0.23 μSv/h) on the basis of a conservative assumption made a great impact on :
  - People's lifestyle in the non-evacuation areas
  - People's decision to return to the evacuation areas
  - Costs of decontaminations and time to lifting the evacuation order

  Etc.

- "Spell of 1 mSv" made it difficult to explain :
  - Why is below 20 mSv/yr OK ?
  - Risk levels? (Not Safe or Dangerous)
  - Why we have to accept risk above 1 mSv/yr?
  - What is an acceptable level of risk, and how is an acceptable level of risk determined ?

Lessons Learned through our study (2)

- D-shuttle enabled to understand and communicate realistic individual external dose in their daily life .
- Personal attitudes toward D-shuttle measurement data are not always the same. When showing measured dose data, some feel secure (e.g., if below 1 mSv/y) and some feel uneasy (e.g., if above 1 mSv/y).
- Risk-tradeoffs

    e.g., radiation risk vs. the long-term health impact of evacuation

Once the regulatory decisional standard was set and penetrated to the public, it is very difficult to change or moderate the initial standard (especially in Japanese regulatory framework ?).

Need to prepare a flexible framework to update the risk management decision if the gap between the conservative estimate and the realistic estimate identified

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Acknowledgements – Thanks -

- The study participants from the Fukushima Prefecture
- Dr. Yujirou Kuroda from Fukushima Medical Univ.
- Dr. Hideki Ishii from Fukushima Univ.

http://www.vill.iitate.fukushima.jp/shoukai/gaiyou.html