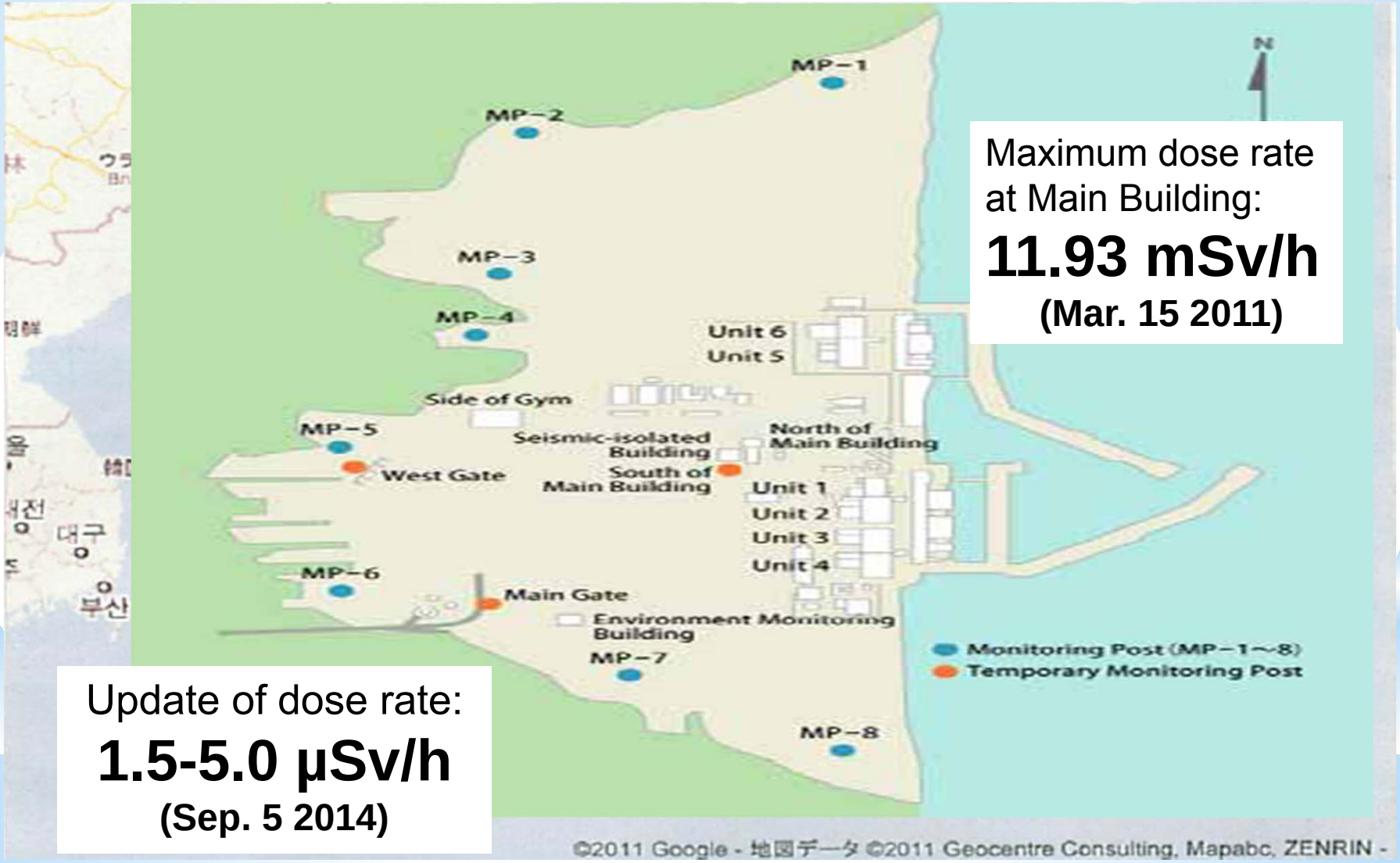
# Variability of radon ($^{222}Rn$) in soil air under a temperate deciduous forest in Fukushima, Japan

Ryoko FUJIYOSHI*, Misato OHNO, Kazumasa OKAMOTO, Kikuo UMEGAKI

Faculty of Engineering, Hokkaido University, Sapporo,JAPAN

# Why radon in Fukushima?

# Fukushima Daiichi Nuclear Power Plant Accident in Mar. 11 2011




Maximum dose rate at Main Building:

**11.93 mSv/h**

**(Mar. 15 2011)**

Update of dose rate:

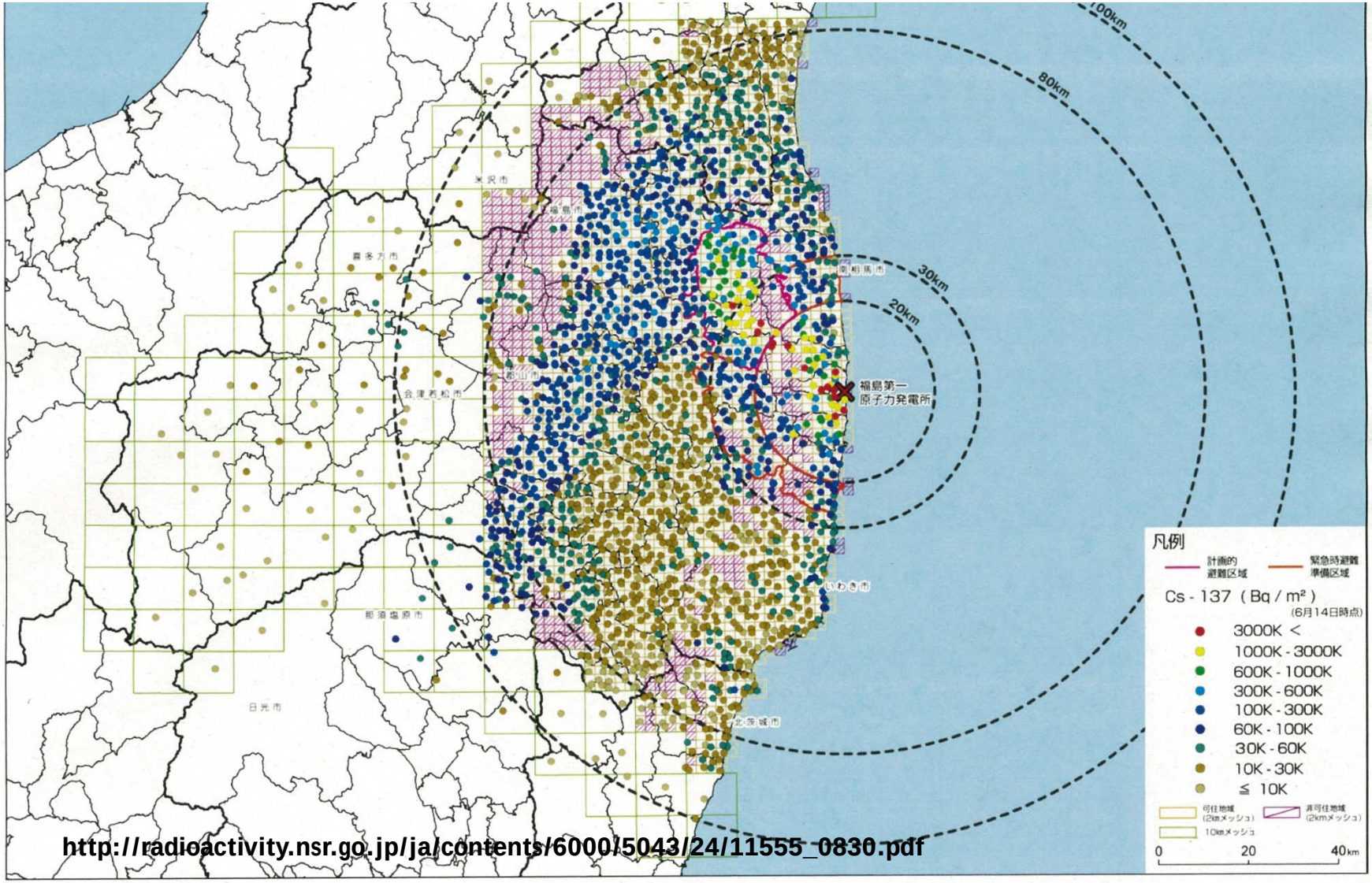
**1.5-5.0 μSv/h**

**(Sep. 5 2014)**

# View of the accident of Fukushima Daiichi Nuclear Power Plant on Mar. 11 2011

http://photo.tepco.co.jp/cat1/01-j.html

# Mapping of $^{137}Cs$ activity concentration in surface soil as of June 14 2011




http://radioactivity.nsr.go.jp/ja/contents/6000/5043/24/11555_0830.pdf

# Fukushima environment now

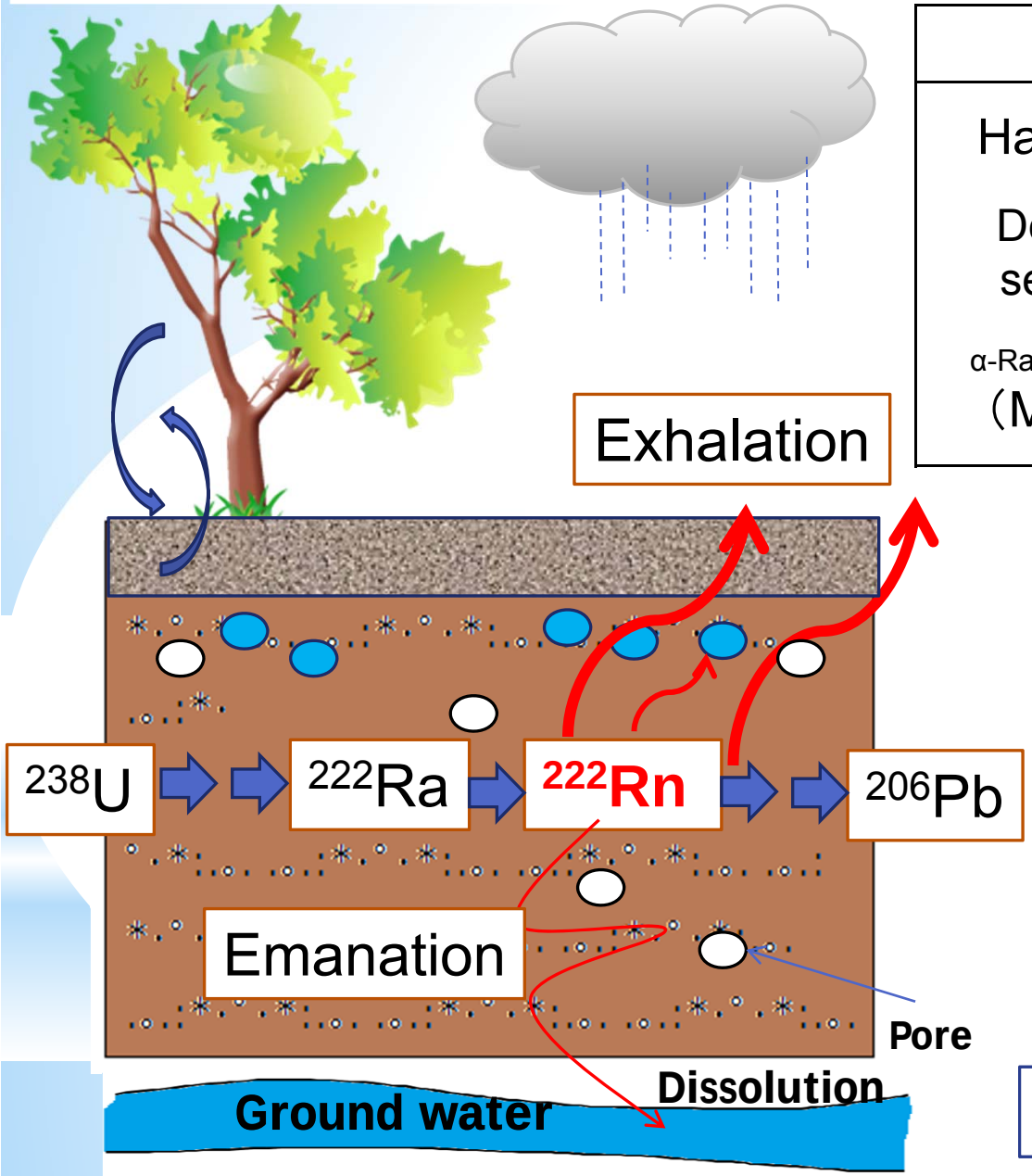
## Decontamination

According to the Ministry of Environment, Government of Japan, decontamination activities in highly contaminated areas in Fukushima Prefecture have resulted in **50 % decrease** in mean radiation dose rate compared with those obtained in two years ago (http://josen.env.go.jp/en/)

It is still difficult to clean up the **forest area** covered 60 % of total land of Fukushima Prefecture. They are dividing three parts: i) close to the residential area (around 200m from forest edge), ii) areas for mushroom cultivation, and iii) remaining area. The first two divisions are gradually proceeding decontamination.

# Fate of long-lived fallout nuclides ($^{137}Cs$) deposited on the ground surface with soil air (and water) movement

# Radon as a useful tracer




**Properties of radon isotopes**

| | $^{219}$Rn | $^{220}$Rn | $^{222}$Rn |
|---|---|---|---|
| Half life | 3.9 s | 55 s | 3.8 d |
| Decay series | $^{235}$U | $^{232}$Th | $^{238}$U |
| α-Ray energy (MeV) | 6.946 | 6.404 | 5.490 |

**Continuous soil $^{222}$Rn monitoring**

**$^{222}$Rn level, variability soil & meteorological parameters**

**Soil air movement**

# Location of the site

## Campus forest

37.6845N, 140.4534E

Annual mean temperature：12.8 ℃

Annual mean precipitation： 1105 mm

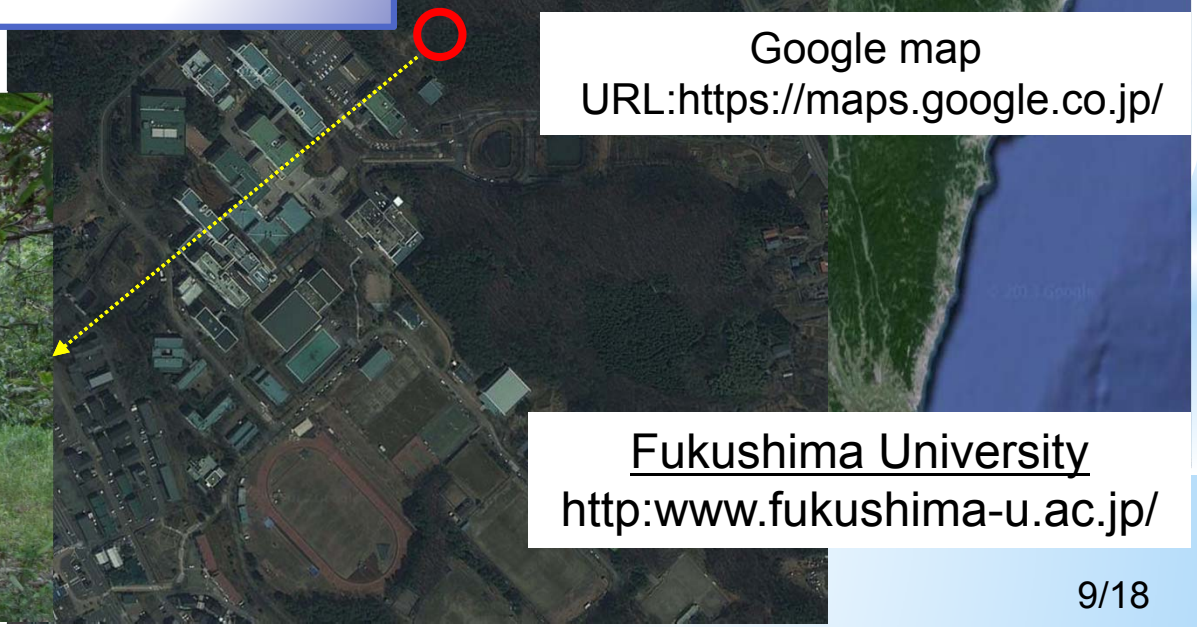
Mean snow depth：8 cm

Stand: Temperate deciduous forest

August 21 – December 6 2013




Google map
URL:https://maps.google.co.jp/



Fukushima University
http:www.fukushima-u.ac.jp/

# Methods

Measurements:

1. **Soil properties** (humidity, porosity, density, pH, soil organic matter)
2. **$^{222}$Rn activity concentration**
   Soil temperature
   Barometric pressure
   Solid state Si detector (VDG system, Algade, France)
3. **Micro barometric pressure**
   (North One Co.Ltd. Japan)
4. **Radioactivity ($^{134}$Cs,$^{137}$Cs,$^{226}$Ra)**
   HPGe detection system
   (SEIKO EG&G, Japan)

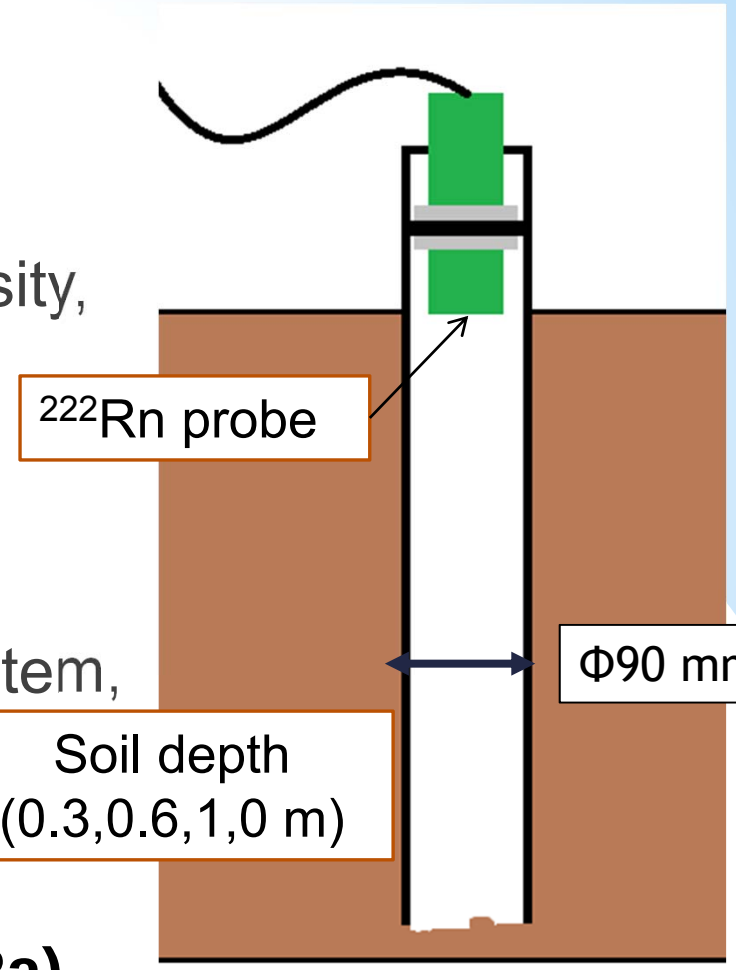
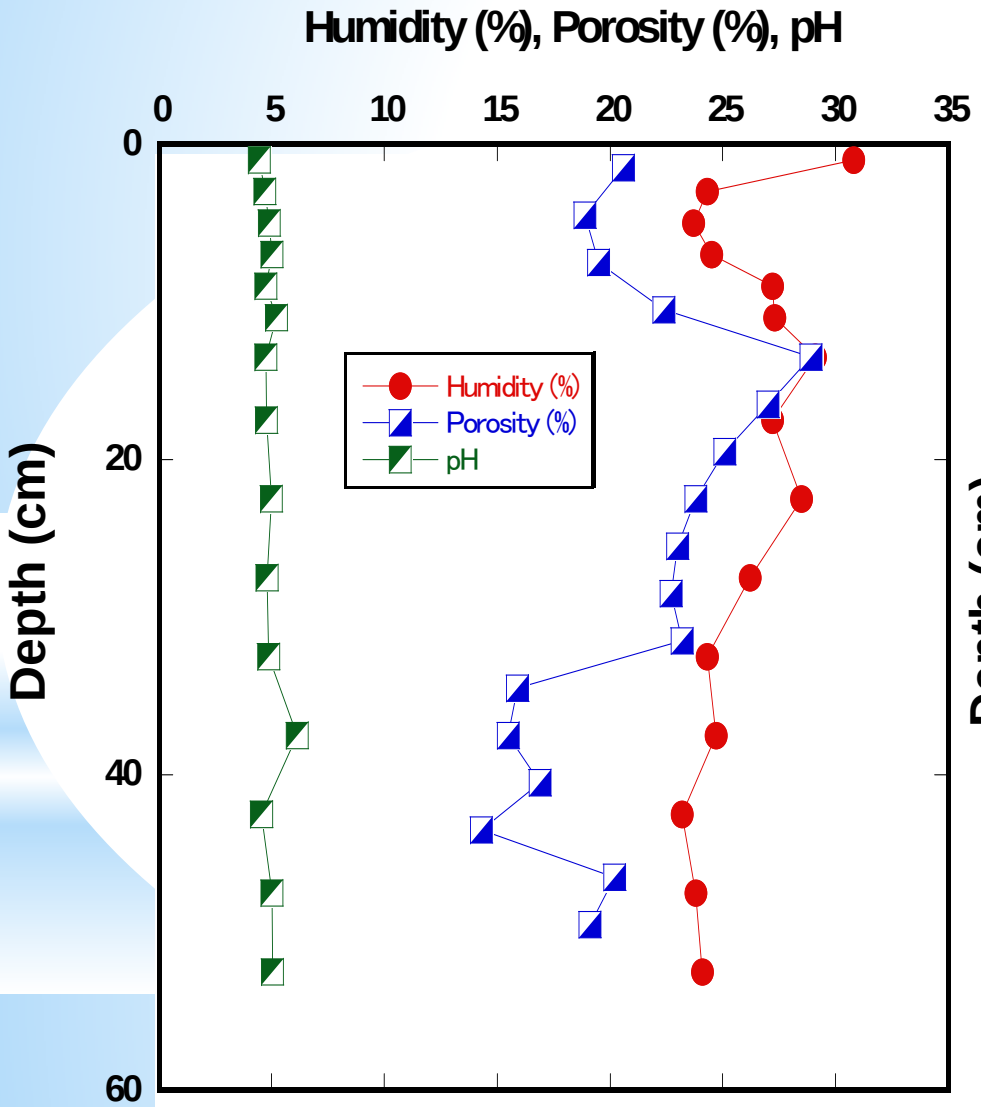
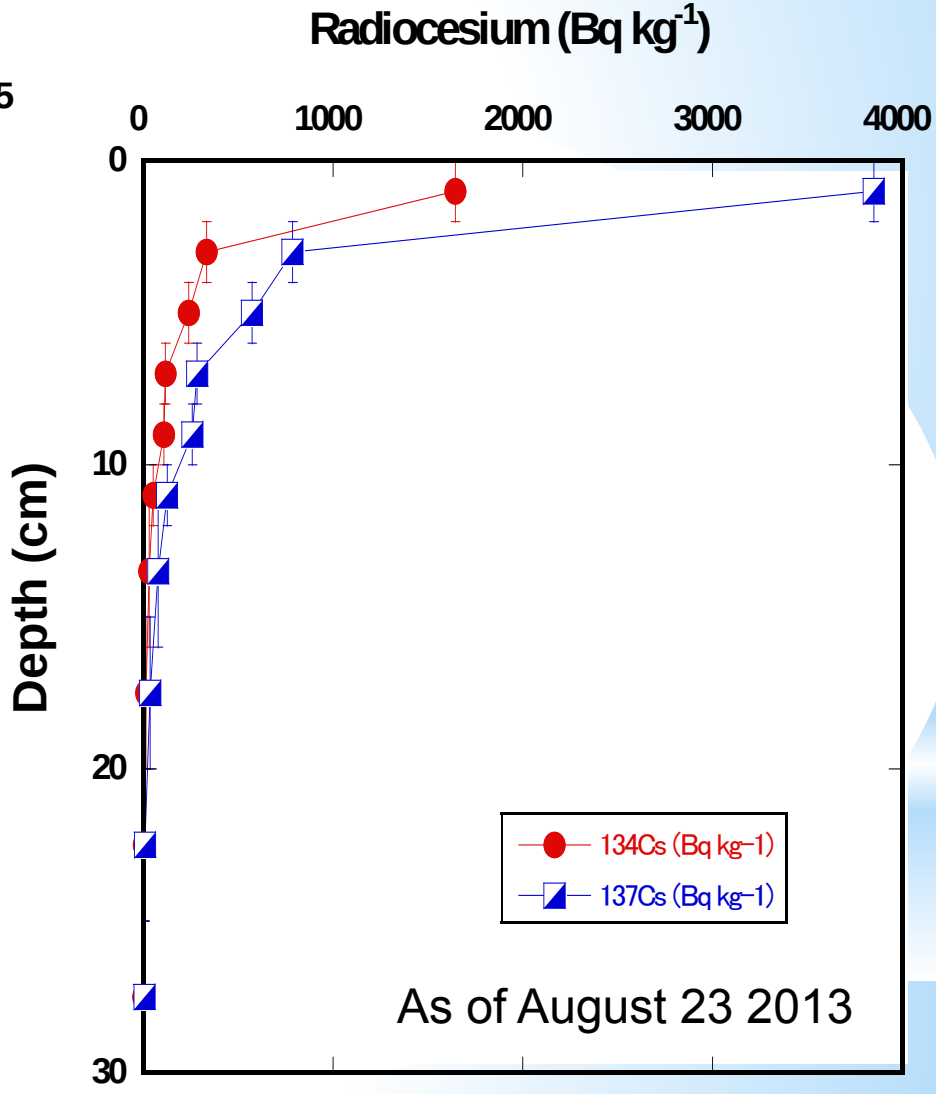



Photo: Probes buried in soil

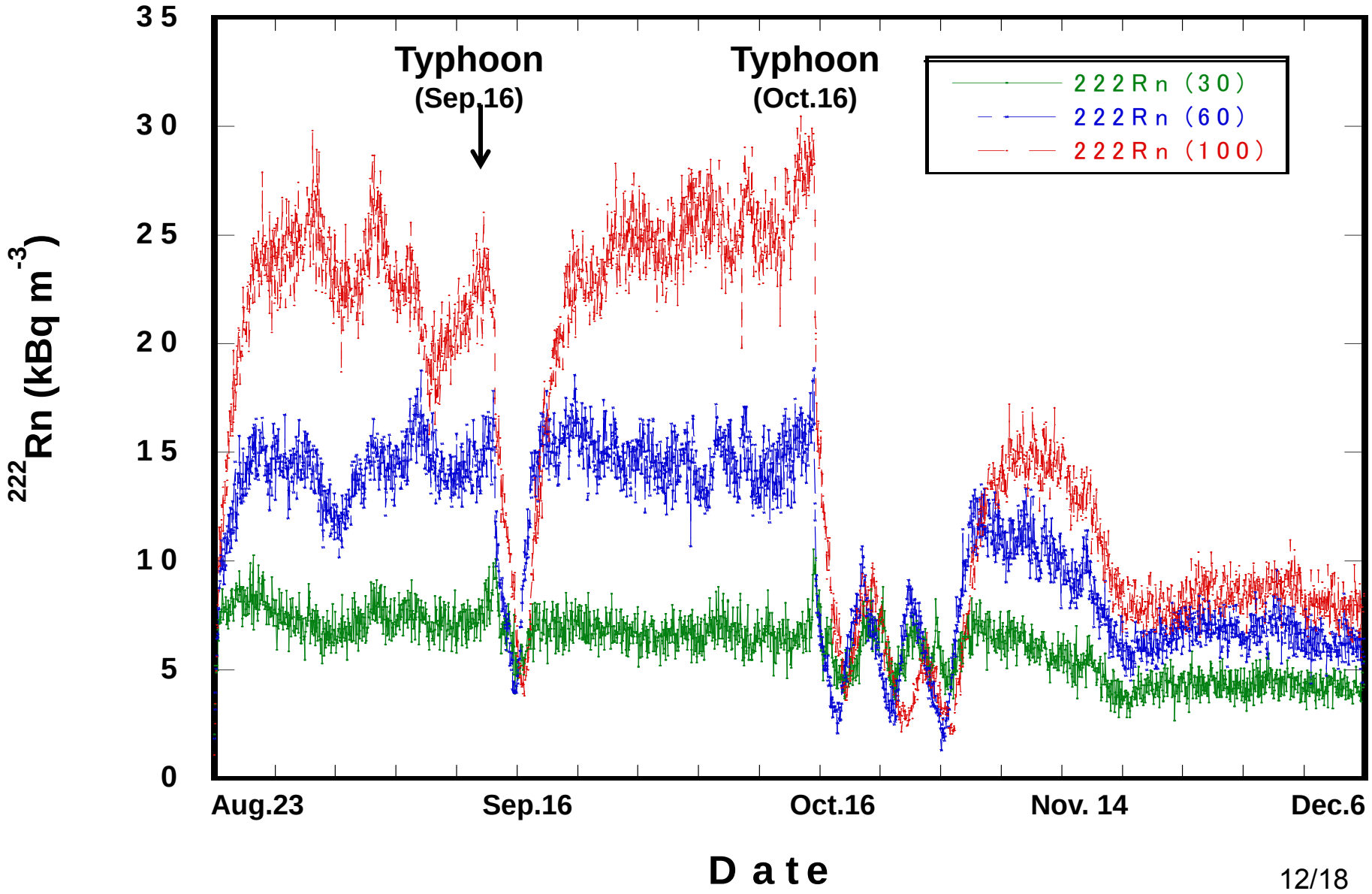
# Depth distribution profiles

(humidity, porosity, pH, $^{134}Cs$, $^{137}Cs$)

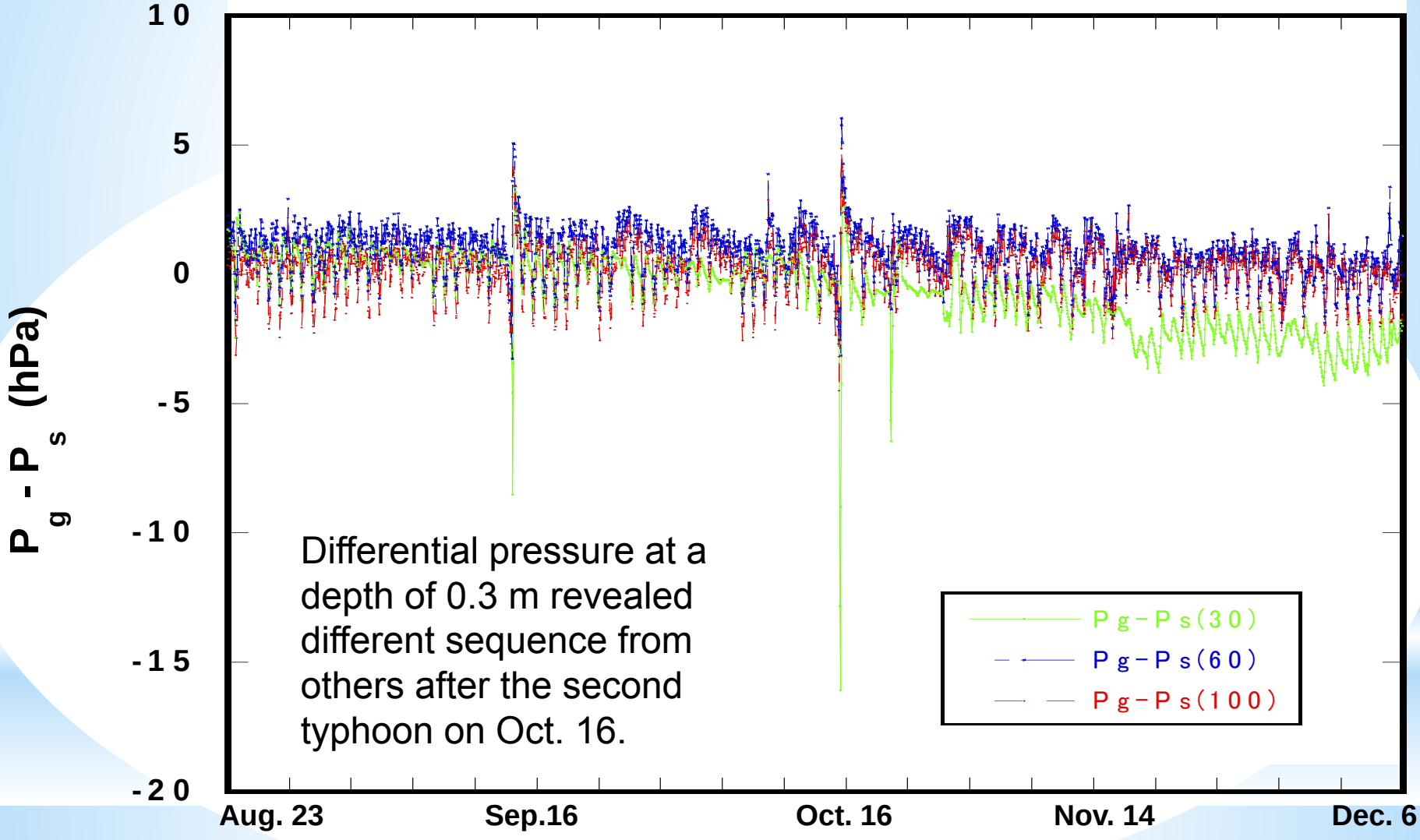


# Time series of $^{222}$Rn activity concentration in soil air at different depths



# Time series of differential barometric pressure measured at different soil depths

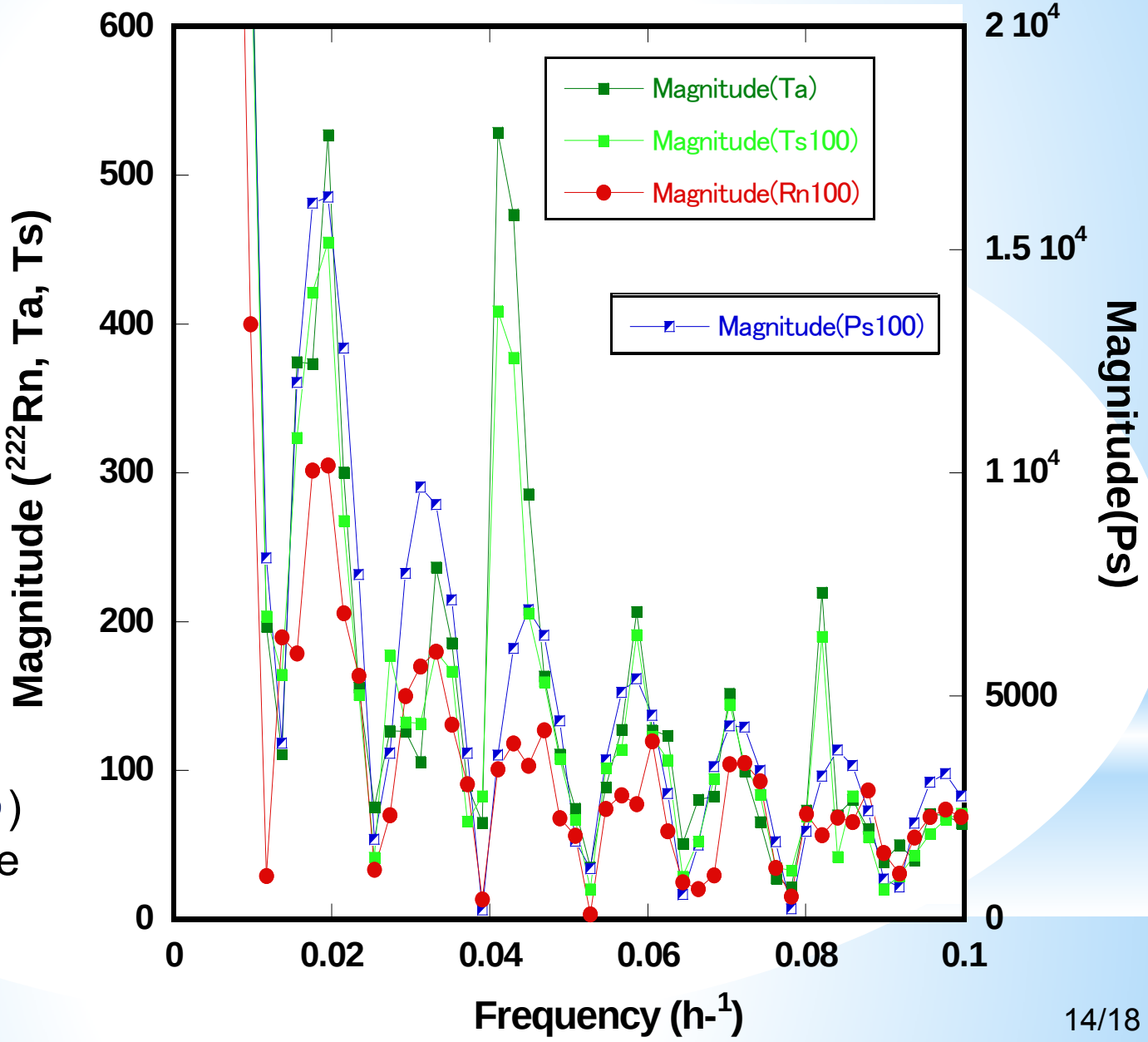


# Periodic variability of soil Rn

Diurnal changes in $^{222}Rn$ concentration appeared under high pressure region from Aug. 23 to Sep. 10 in 2013

$^{222}Rn$ ( ) changed depending on soil and meteorological parameters:

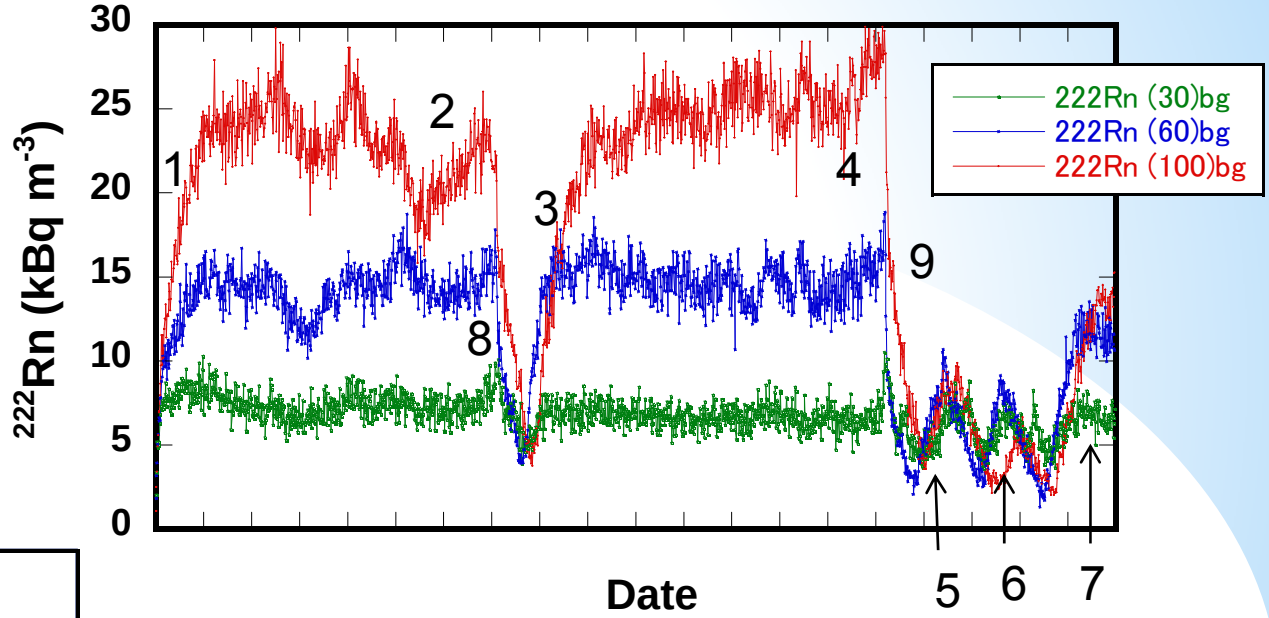
- atmospheric temperature ( )
- soil temperature ( )
- barometric pressure in soil ( )

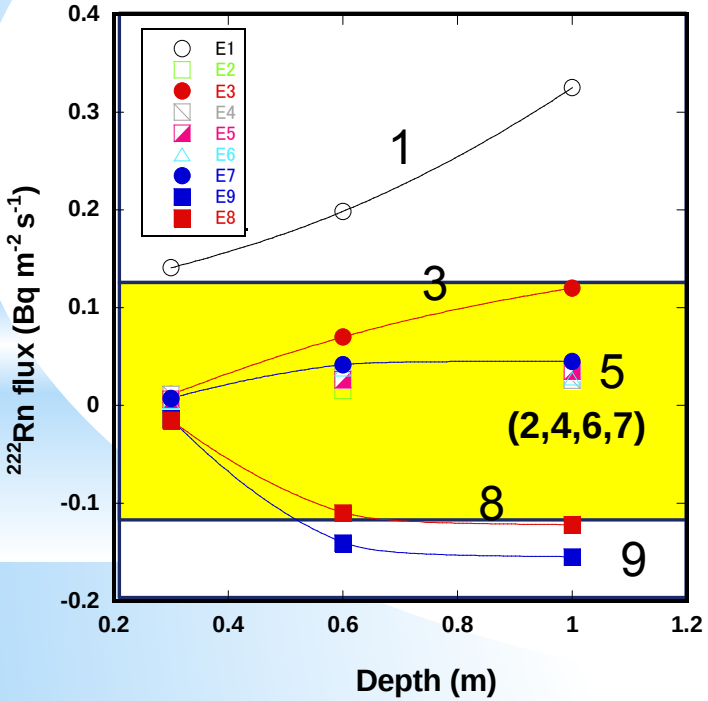


# Soil $^{222}$Rn flux during the observation periods

**Aug. 23 – Nov.2 2014**

Focusing on **9** events in which increasing and decreasing $^{222}$Rn were observed at any depth




$^{222}$Rn effective diffusion coefficient

⇩

Depth dependence of $^{222}$Rn concentration

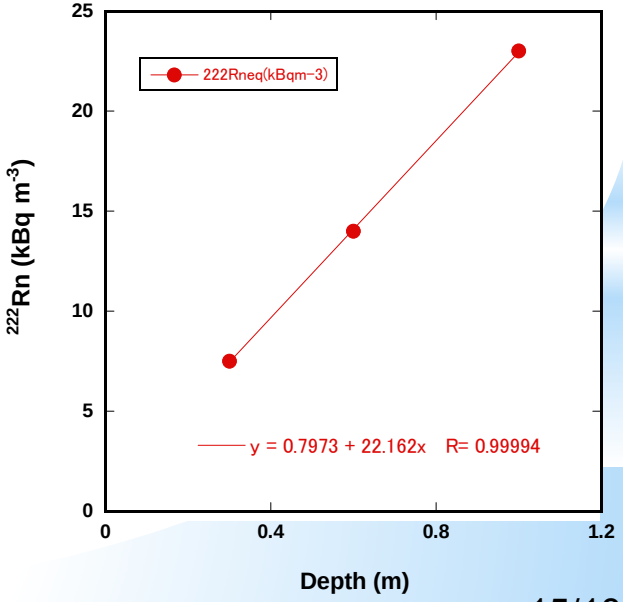
⇩

$^{222}$Rn flux

⇩

**$^{222}$Rn transportation**

Diffusion-controlled



# Summary

Soil $^{222}$Rn concentration at different depths

Surface (0.3 m) < Deeper (1.0 m)

↓

Affected by meteorological parameters

Atmospheric pressure & temperature (Typhoon)

High atmospheric pressure: diurnal variability

$^{226}$Ra activity concentration (30 Bq kg$^{-1}$)

Soil porosity (15～30 %)

**Equivalent concentration of $^{222}$Rn**

↓

Estimating $^{222}$Rn flux

（diffusion-controlled transportation）

# Acknowledgements

Special thanks should be given to **Prof. Akira WATANABE** of Fukushima University for helping start and continue monitoring on the campus forest. Also thanks to **Mr. Toshihiko HATANO** and **Mr. Masato YAMAKAWA** of North One Co.Ltd (Sapporo, Japan) for advising instrumentation of the probes (differential barometric pressure and soil humidity) in the field. I would appreciate **Dr. Claude BELTRAND** of Algade (France) for useful comments and suggestions on soil $^{222}Rn$ monitoring.

This work has been supported by Japan Science and Technology Agency (JST) on a research theme with a title of “Multidisciplinary investigation on radiocesium fate and transport for safety assessment for interim storage and disposal of heterogeneous wastes” (Tamotsu KOZAKI, Hokkaido University, Japan) from FYs 2012- 2014.

Some figures on pages 9, 11 and 12 in this presentation were cited from our paper published in Environ. Earth Sci. (ISSN: 1866-6280, DOI:10.1007/S12665-014-3693-8)

# Thank you for your attention!

Kafir lily, one of my favorite flowers, Ryoko FUJIYOSHI