Investigation on distribution of radioactive substances in Fukushima
(9) Analysis of temporal changes in ambient dose equivalent rates in forests over 6 years following the FDNPP accident

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Abstract
We analyzed changes in ambient dose equivalent rates ($H^*(10)$) between 2011 and 2017 in forests in Fukushima Prefecture. PHITS was used to calculate the effect of re-distribution of $^{134}$Cs and $^{137}$Cs over time within forests on $H^*(10)$. Transfer of radiocesium from the crowns of evergreen coniferous trees to the forest floor appeared to cause slower declines in $H^*(10)$ at 1 m height initially after March 2011 than expected by the rate of radiocesium decay.

Keywords: forest, environment, ambient dose equivalent, radiocesium, $^{134}$Cs, $^{137}$Cs, FDNPP accident, PHITS, Monte Carlo, simulation

1. Introduction
Ambient dose equivalent rates ($H^*(10)$) have been observed to decrease more slowly in forests than in other areas since the 2011 Fukushima Daiichi Nuclear Power Plant (FDNPP) accident [1]. Moreover, between 2011 and 2013, $H^*(10)$ at 1 m above the ground in some forests decreased slower than the rate of radioactive decay of the radiocesium fallout [2]. The reasons for this behavior were examined by using radiation transport simulations.

2. Methods
Forests in Fukushima Prefecture monitored by FFPRI [3] were modelled with the PHITS code [4]. We calculated the contributions to $H^*(10)$ at 1 m above the ground from $^{134}$Cs and $^{137}$Cs in the canopy, trunks, organic layer, and soil layers separately. The results were compared to $H^*(10)$ measurements from hand-held survey meters.

3. Results
Yearly fluctuations in the measured $^{134}$Cs and $^{137}$Cs inventories in forests meant the inventories had to be normalized to a common baseline to understand the effects of re-distribution of $^{134}$Cs and $^{137}$Cs within forests on $H^*(10)$. The results show that changes in the distribution of $^{134}$Cs and $^{137}$Cs on the centimeter scale within the organic layer and soil affect the temporal trends of $H^*(10)$ in forests.

4. Conclusions
The slower decreases in $H^*(10)$ in forests compared to other land uses was a consequence of the high retention of $^{134}$Cs and $^{137}$Cs by forests, and the tendency of $^{134}$Cs and $^{137}$Cs to remain near the top surface of forest soil. Radiocesium transfer from the crowns of evergreen coniferous trees to the forest floor explained a slower rate of decline in $H^*(10)$ between 2011 and 2013 than expected by the rate of radioactive decay.

References