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Long term and wide prediction of radioactive diffusion by means of levy flight model

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We applied the Levy-flight model for estimating the special distribution of surface radioactivity in Fukushima. The reason why we use the Levy-flight model is that the data, measured in the 50 km vicinity of Chernobyl, follow the model.

We analyze the data of Chernobyl and found that the surface concentration of a specific radionuclide, such as Cs-137, decreases with the power law (that is one of the characteristics of the Levy-flight model) as the distance from the hypocenter increases. Of course, the surface concentration should be strongly site-specific, depending on many conditions, especially geomorphological or meteorological. However, we would think that it is still useful to make a rough estimate of the spatial distribution of the pollution.

The Levy-flight model is one of the stochastic models. A Levy flight is a random walk in which the step-lengths have a certain probability distribution that is fat-tailed. In the present study we use the power function as the probability distribution. In the two-dimensional space, the steps made are in isotropic random directions. The trajectories of Levy flight are a mix of long and short trajectories. The difference of this model from the ordinary Brownian motion is that the Levy flight produces extremely long trajectories sometimes. Such kind of randomness can be found in turbulent fluids. It is also known that the Levy flight is related with the fractal science. Some studies show that a fractional-differential equation corresponds to the density of particles which are doing Levy flights.

In the following, we explain how we apply the Levy-flight model to the surface radioactivity. We assume that the radionuclides, which had been deposited on the ground, spread mainly by wind. According to the studies about resuspension, it is known that resuspension occurs when the wind velocity is larger than a threshold value. If the wind velocity is below the threshold, radionuclides are not suspended in the air and do not move. We regard the movements of suspended nuclides as the long flights of Levy flights, because the radionuclides are carried for a long distance during suspension. Immobile nuclides are regarded as short Levy flights. Artificial disturbances such as agriculture or traffic should be affect significantly to the movement of radionuclides. However, we assume them negligible, since we deal with a wide-range behavior of radionuclies in this study. In wide region such as 30 km, artificial disturbances may be small enough, compared with natural winds that blows all over the region, and all time.

The procedure of our calculation is as follows. We define the parameters of Levy flights, using the measured data of Chernobyl. The probability of existence of a particle of the Levy flight corresponds to the surface concentration. Then we calculate the special- and temporal evolution of the concentration by means of solving numerically a fractional-differential equation. Following Grunwalt-Letnikov formula, we use the software Mathematica and obtained the special distribution of the surface concentration.

Keywords: radionuclide, Levy flight, Fukushima, Chernobyl, simulation