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Improvement of Assessment Methods for Atmospheric Behavior of Hazardous Materials by Comprehensively Analyzing Nuclear Accident Data

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The main aims of this study are three-fold. The first one is to compile atmospheric data capturing the plume behavior in the very early stage of the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident. The second one is, by holding international model intercomparison projects (MIPs), to evaluate state-of-the-art atmospheric transport models in the world. The final one is to propose a prototype scheme of using the atmospheric transport models in the nuclear emergency countermeasure.

A comprehensive set of atmospheric environment data dedicated for the FDNPP accident was complied as shown in Table 1. This data set includes the hourly atmospheric radiocesium concentrations analyzed for more than 200 locations in the eastern part of Japan, supplemented by 10 min interval data of other nuclides including noble gas and radioiodine. The source terms of radiocesium and radioiodine was renewed by using additional environmental data newly obtained. The three-dimensional meteorological fields with fine horizontal resolutions became available. The concentration data obtained in this study revealed eight radioactive plumes in addition to known 19 plumes.

Two series of atmospheric dispersion model intercomparison projects were conducted to examine performance of the existing models. The first project with the 3 km horizontal grid demonstrated that all the twelve models calculated the atmospheric concentrations reasonably as shown in Fig.1 although the wet deposition calculation was the largest source of uncertainty. The second project with the 1 km grid revealed that the refinement in the terrain representation in the meteorological calculation substantially improved the evolution of plume over mountainous areas. A newly developed comparison method using the dose rate data was successfully applied to quantitatively evaluate the performance of the models. Several types of wet deposition schemes and model parameters were tested to find that the calculation results were most sensitive to the choice of scheme followed by the values of model parameters and much less sensitive to schemes of cloud microphysics.

By integrating the ensemble of atmospheric dispersion models and the newly developed method of source term estimation method, a prototype of emergency response scheme was proposed. Its performance was favorably tested with the data set for predictability of plume arrival and concentration levels and for feasibility of source term estimation. It was shown that, if calculation results of several models were available, arrival of plume could be predicted with a probability of prediction failure of about a few percent.

Table 1　Contents of data set made in this study. Items in gray-italic are ones that have been existing at the start of this study.

Category	Contents and specifications (dates in 2011)	References
Meteorological	*East Japan (horiz. grid 3 km), March 11-31, 1 h interval Wind vector, temperature, humidity, precipitation*	Sekiyama et al. 2017
	East Japan (horiz. grid 1 km), same as above	Sekiyama, Kajino, 2020
	Kanto and southern Tohoku (horiz. grid 0.25 km), same as above	Sekiyama, Kajino, 2021
Source terms	*Reverse method, March 12 to April 30, Cs-137, Cs-134, I-131,Te-132*	Katata et al., 2015
	Inverse method, March 12-31, same nuclides as above	Terada et al., 2020
	Inverse method, March 12-31, Cs-137, I-131	Under preparation
Atmospheric concentration (observation)	*Tokyo metropolitan area, Tohoku SPM 149 stations, Marchi 12-23, 1 h interval, Cs-134, Cs-137*	Oura et al., 2015 Tsuruta et al., 2014,2018
	Tokai-Koshinetsu SPM 78 stations plus 19 stations among above-mentioned ones, March 24-31	Under preparation
	Ibaraki, 6 radiation monitoring stations, March15,16,20-22, 10 min interval, Xe-133, I-131,132,133, Te-132, Cs-134,136,137	Terasaka et al., 2016
	Ibaraki, 15 radiation monitoring stations, March 15, 10 min interval, Xe-133,I-131,132,133,Te-132	Moriizumi et al., 2020
Calculated data	Horiz. grid 3 km, March 12-31, 1 h interval, 12 models Atmos. conc.、 wet and dry depositions, surface wind	Sato et al., 2018
	Horiz. grid 1 km, March 12-24, 1 h interval, 9 models Same data items as above	Sato et al., 2020

SPM: Suspended Particulate Matter

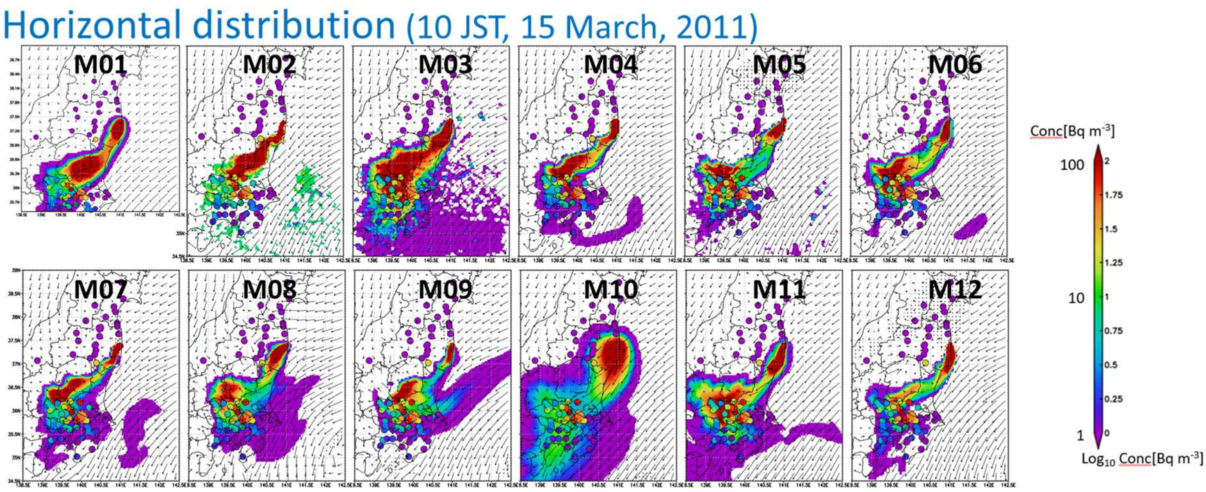

Fig.1　Example of the results obtained in the MIP. Atmospheric Cs-137 concentration at the surface level calculated by 12 models was compared with observation shown by circles.