Analysis on the formation process of high dose rate zone in the northwest direction of the Fukushima Daiichi nuclear power plant

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Research group of Japan Atomic Energy Agency (JAEA) has analyzed the formation process of high dose rate zone in the northwest direction of the Fukushima Daiichi nuclear power plant and the middle part of Fukushima Prefecture by using numerical simulations of the atmospheric dispersion of radioactive materials discharged from the plant during the period from 15 to 16 March, 2011.

The numerical simulation reproduced the atmospheric dispersion of radioactive materials as follows. The radioactive plume discharged in the morning of 15 March flowed toward the south to southwest direction from the plant, then moved westward around noon and encountered a rain band at the middle part of Fukushima Prefecture from 14 to 15 JST (Japan Standard Time). The deposited radionuclides by rainfall caused the increase of air dose rates at the monitoring posts in Shirakawa and Koriyama cities. On the other hand, the radioactive plume discharged in the afternoon of 15 March flowed toward the west to northwest direction from the plant. It was washed out by a rain band moved from the northwest direction and deposited on the ground over the northwest area of the plant during the period from the evening to midnight of 15 March. The simulation shows that the deposition by rainfall at the middle part of Fukushima Prefecture occurred earlier than that around the northwest direction from the plant, and this result agreed with the monitoring data by Fukushima Prefecture. While the radioactive plume flowed toward the Pacific Ocean after the morning of 16 March, dose rates around the northwest region of the plant and the middle of Fukushima Prefecture continued to be high in both simulation results and monitoring data. It indicates that the current high dose rates monitored in Fukushima prefecture are caused by radionuclides deposited on the ground due to the rainfall on 15 March.

In order to best reproduce the spatial and temporal distributions of air dose rates in monitoring data, the release rates of radionuclides were assumed to increase substantially during separate 3-hour periods before and afternoon of 15 March. These significant increases of release rates of radionuclides are also indicated by the increase of air dose rate monitored at the main gate of the plant during 7:00 to 10:30 in the morning and the rapid decreases of pressure in Unit 2 in the morning and afternoon.

This simulation was carried out by using the nuclear emergency response system of JAEA, WSPEEDI: World-wide version of System for Prediction of Environmental Emergency Dose Information. Although the simulation has some discrepancies with measurements, such as overestimations around northern part of Fukushima city and southeastern part of Koriyama city, spatial and temporal distributions of air dose rates agree mostly with those derived from monitoring data on the ground and by airplane.

This work including technical details is presented in the special session "Fukushima Crisis: Air/Sea Transport Modeling" of 15th Annual George Mason University Conference on Atmospheric Transport and Dispersion Modeling held at Fairfax, Virginia, U.S.A. on 12 to 14 July, 2011.

Calculation Conditions

Calculation domain:	190 km square around the plant, 1 km resolution
Calculation period:	17 JST 14 to 00 JST 17 March, 2011
Meteorological data:	GPV (Grid Point Value) data by Japan Meteorological Agency, AMeDAS (Automated Meteorological Data Acquisition System) data
Topographical data:	1 km grid surface elevation and land-use data
Radionuclides:	^{131}I, $^{132}Te + ^{132}I$, ^{134}Cs, ^{137}Cs
Release rate:	Based on the preliminary estimated source term reported by Nuclear Safety Commission of Japan, temporal changes of release rates are determined to reproduce the monitoring data.

Supplementary figures

Fig. 1 Simulated atmospheric dispersion process on 15 to 16 March, 2011

As shown in the upper panels, the simulation reproduced temporal changes in air dose rate measured at the middle part of Fukushima Prefecture (Koriyama city), where the radioactive plume discharged in the morning was passed, and the northwest part of the plant (Iitate mura), where the radiation plume discharged in the afternoon was passed.

In the middle panel, the distribution of simulated air dose rate at 21 JST on 16 March is shown together with arrows schematically representing plume paths during the period from 15 to 16 March. The clockwise rotation in plume flow direction is shown.

In the bottom panel, time series of air dose rate at the main gate and the periods of rapid decrease of pressure data* in Unit 2 are shown. While the increase of air dose rate and the decrease of pressure in the morning occurred almost concurrently, no clear peak in air dose rate detected corresponding to the decrease of pressure in the afternoon due to about 90-degree turn in wind direction.

*Pressure data: NISA (http://www.nisa.meti.go.jp/oshirase/2011/files/230411-1-3.pdf)

Fig. 2 The movement of radioactive plume and rain bands: left panels show calculated (shaded area) and measured (plot with values) air dose rate, and right panels show calculated rain intensity (shaded area) and concentration accumulated in vertical air column (red contours).

- The plume discharged in the morning flowed toward the southwest direction. While the plume did not encounter rain bands during the morning and air dose rates decrease down to a low level after its passage, it encountered a rain band at the middle part of Fukushima Prefecture around 15 JST causing high dose rate zone.

- The plume discharged in the afternoon flowed toward west to northwest direction and encountered a rain band after evening, causing a large amount of wet deposition around the northwest region.
- The plume flowed out to the Pacific Ocean after the morning of 16 March. Since dose rates around the northwest region of the plant and the middle of Fukushima Prefecture continued to be high, these high dose rates are caused by radionuclides deposited on the ground due to rainfalls.
- The simulation has some discrepancies with measurements, such as overestimations around northern part of Fukushima city and southeastern part of Koriyama city. It is caused mainly by temporal and/or spatial discrepancies in rain area between the actual condition and simulation during plume passage, and overestimation of upper wind speed.

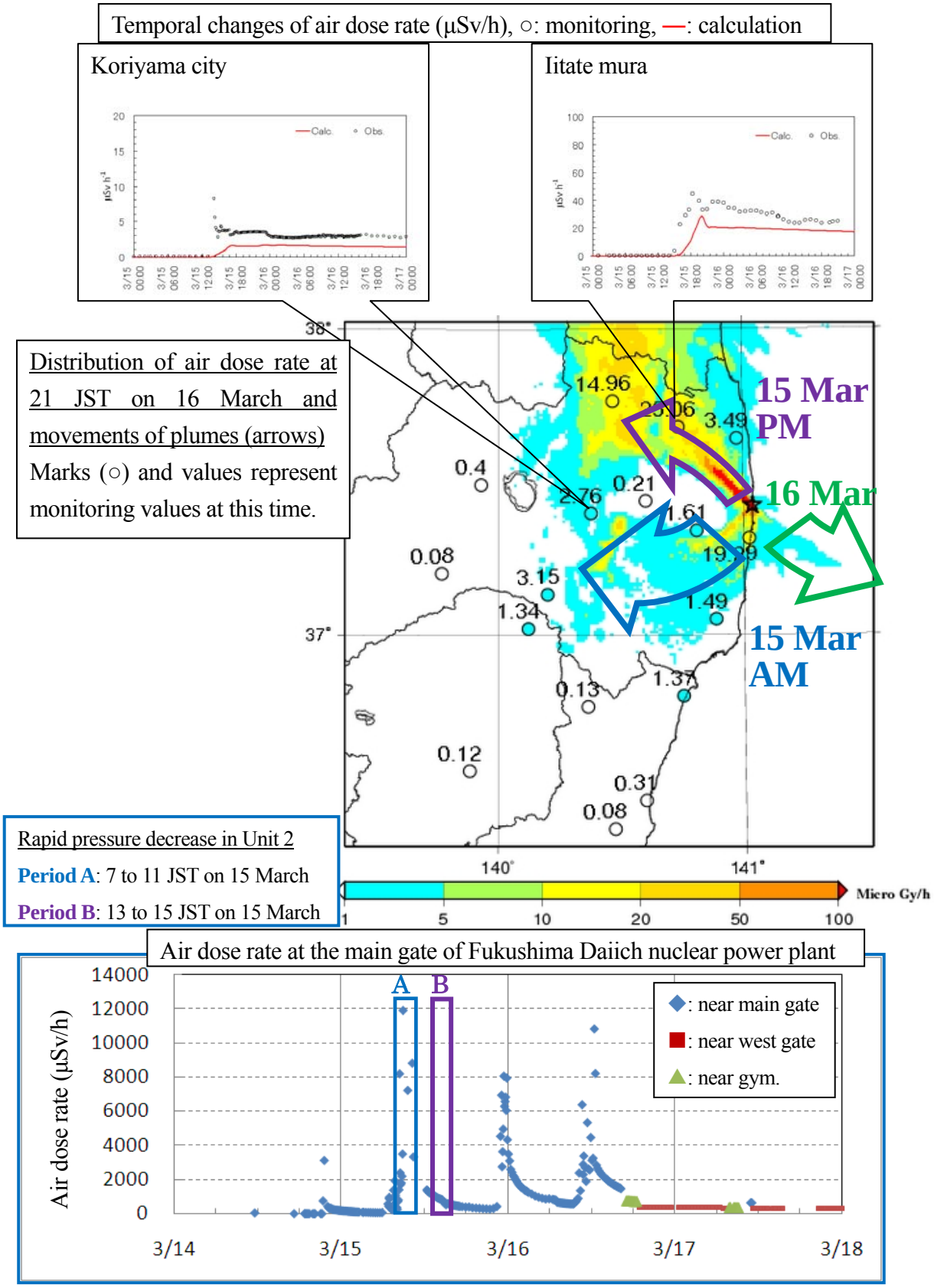
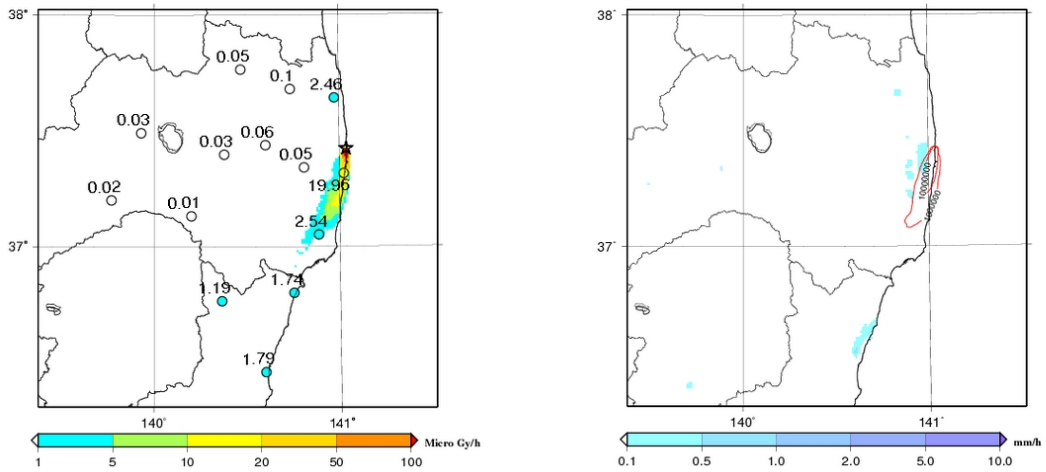
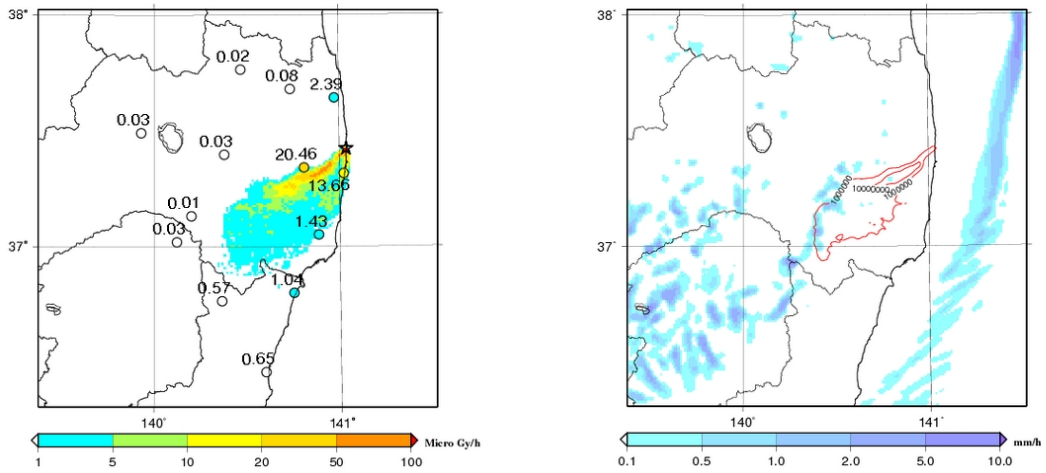


Fig. 1 Simulated atmospheric dispersion process on 15 to 16 March, 2011

09 JST on 15 March, 2011



12 JST on 15 March, 2011



15 JST on 15 March, 2011

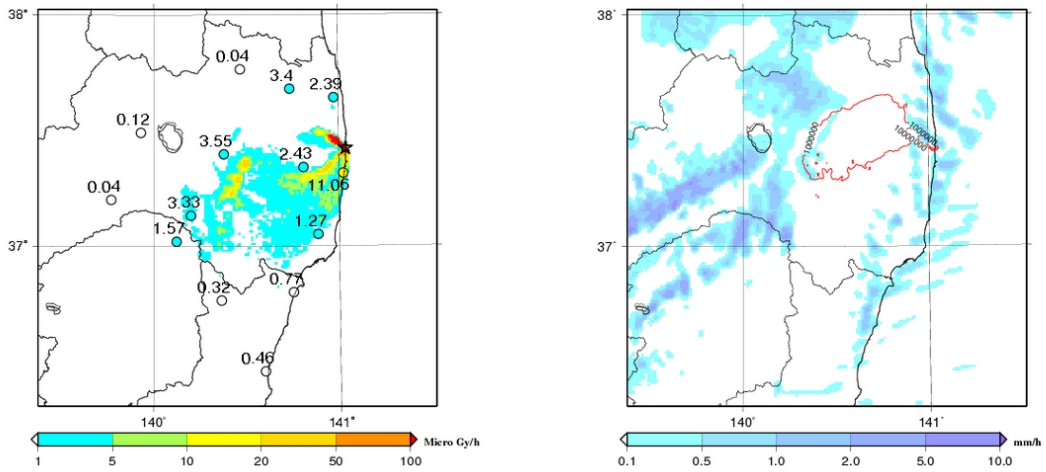
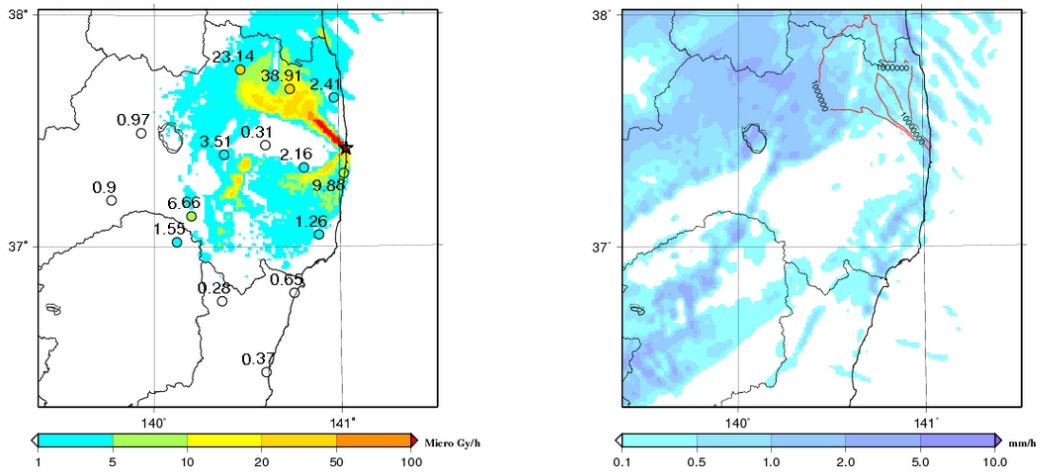
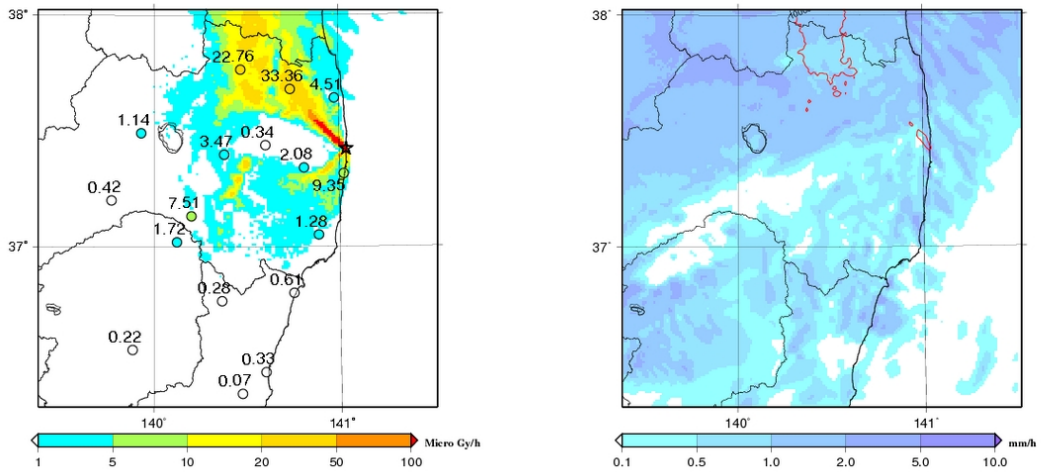


Fig. 2 Left panel: calculated (shaded area) and measured (plot with values) air dose rate, and right panel: calculated rain intensity (shaded area) and concentration accumulated in vertical air column (red contours)

18 JST on 15 March, 2011



21 JST on 15 March, 2011



09 JST on 16 March, 2011

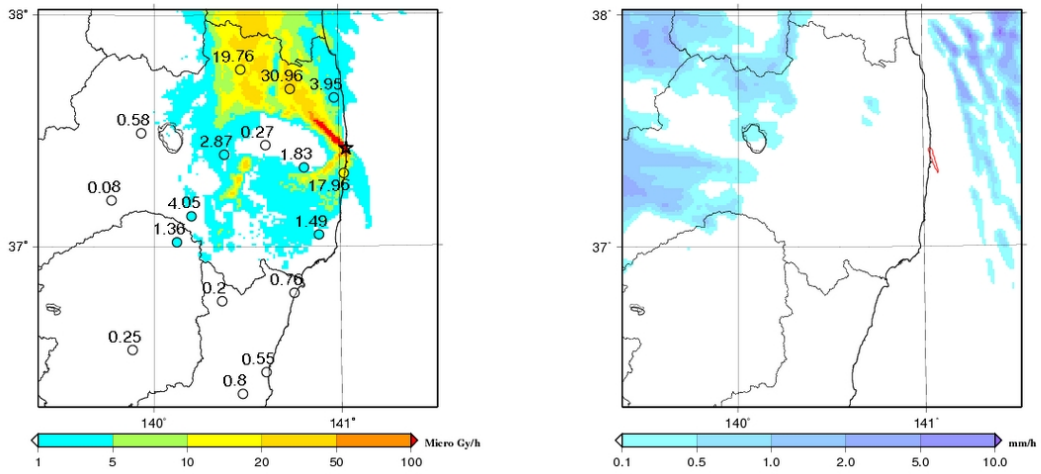


Fig. 2 continued