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Ensemble Simulation of the Atmospheric Radionuclides Discharged by the Fukushima Nuclear Accident

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Enormous amounts of radionuclides were discharged into the atmosphere by a nuclear accident at the Fukushima Daiichi nuclear power plant (FDNPP) after the earthquake and tsunami on 11 March 2011. The radionuclides were dispersed from the power plant and deposited mainly over eastern Japan and the North Pacific Ocean. A lot of numerical simulations of the radionuclide dispersion and deposition had been attempted repeatedly since the nuclear accident. However, none of them were able to perfectly simulate the distribution of dose rates observed after the accident over eastern Japan. This was partly due to the error of the wind vectors and precipitations used in the numerical simulations; unfortunately, their deterministic simulations could not deal with the probability distribution of the simulation results and errors. Therefore, an ensemble simulation of the atmospheric radionuclides was performed using the ensemble Kalman filter (EnKF) data assimilation system coupled with the Japan Meteorological Agency (JMA) non-hydrostatic mesoscale model (NHM); this mesoscale model has been used operationally for daily weather forecasts by JMA. Meteorological observations were provided to the EnKF data assimilation system from the JMA operational-weather-forecast dataset. Through this ensemble data assimilation, twenty members of the meteorological analysis over eastern Japan from 11 to 31 March 2011 were successfully obtained.

Using these meteorological ensemble analysis members, the radionuclide behavior in the atmosphere such as advection, convection, diffusion, dry deposition, and wet deposition was simulated. This ensemble simulation provided the multiple results of the radionuclide dispersion and distribution. Because a large ensemble deviation indicates the low accuracy of the numerical simulation, the probabilistic information is obtainable from the ensemble simulation results. For example, the uncertainty of precipitation triggered the uncertainty of wet deposition; the uncertainty of wet deposition triggered the uncertainty of atmospheric radionuclide amounts. Then the remained radionuclides were transported downwind; consequently the uncertainty signal of the radionuclide amounts was propagated downwind. The signal propagation was seen in the ensemble simulation by the tracking of the large deviation areas of radionuclide concentration and deposition. These statistics are able to provide information useful for the probabilistic prediction of radionuclides.