ATMOSPHERIC DISPERSION MODELING FOR THE FUKUSHIMA NUCLEAR ACCIDENT

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Abstract: A Lagrangian particle model has been used to evaluate the characteristics of the transport and dispersion of radioactive materials released into the atmosphere after the Fukushima accident on March 2011. ^{131}I was affected in human and environment near a Fukushima in the early, otherwise the ^{137}Cs with a half life of 30.1 years had serious effects in the environment due to the atmospheric deposition. Therefore, it is one of the important factors to estimate and evaluate the behaviour of ^{137}Cs in the air and deposited ground.

***Key words:** Lagrangian ,radioactive material, atmospheric deposition.*

INTRODUCTION

On March 11, 2011, an earthquake of magnitude 9.0 occurred on the Pacific Ocean side of northern Honshu in Japan. In the early stage, the nuclear power complex at Fukushima Daiichi shut down automatically but the electric power supply to cool the reactor was flooded by a large tsunami. A melt down occurred soon after the shut down because the rector's cooling system failed. A significant amount of radionuclide was released into the air from the Fukushima nuclear accident due to the Great East-Japan earthquake and tsunami. The concentrations in the air and on the surface were calculated and the dose rate by radionuclides released into the environment was also evaluated. A Lagrangian particle model named LADAS (Long-range Accident Dose Assessment System) (Suh, K.S. et al., 2009) has been used to evaluate the characteristics of the long-range transport and dispersion of radioactive materials released into the atmosphere. The radionuclides of I-131 and Cs-137 were considered to compute the radiological dose affected in human beings and the environment. LADAS on March 12, 2011 was operated to evaluate the radiological effects for the Fukushima accident. In the early stages of the accident, source term information such as radionuclide, release rate and duration could not be known owing to the damage of the monitoring systems near the Fukushima power plant. Therefore, the source rates of I-131 and Cs-137 was assumed with the unit amount. On April 12, 2011, the Japan Atomic Energy Agency announced that the total amounts of I-131 and Cs-137 released into the atmosphere were 1.5 x 10^{17} and 1.3 x 10^{16} Bq, respectively. The most of calculated concentrations moved over the east area in Japan, but some radionulides were deposited over the northwest area from the Fukushima power plant due to the south-easterly wind and precipitation.

LAGRANGIAN PARTICLE MODEL

The particle tracking model was used for the estimation of the concentration distribution of the radioactive materials released into the atmosphere. The model was designed to estimate air concentration and dry deposition as well as a wet deposition at distances of up to several thousands of kilometers from the source point in a horizontal direction. The turbulent motion is considered to separate the treatment of particles within the mixing layer and those above the mixing layer. The concentration in the Lagrangian particle model is calculated in the domain of interest by counting the number of particles in an arbitrary control volume. The concentration is equal to the number of particles divided by the volume of the box. Removal processes into the atmosphere are also considered with the dry/wet deposition and radioactive decay in the model. Lagrangian type models can treat the rapid concentration gradient near a source point easily and don't also cause the numerical dispersion. The mixing heights are calculated by the bulk Richardson number (Vogelezang,D.H.P. and A.A.M. Holtslag, 1996). The method is fairly accurate and is suited for use in numerical weather prediction models where some resolution is possible within the boundary layer. The mixing height is defined as the height where the bulk Richardson number reaches a critical value of $R_{ih}=0.25$. The air dose rate, external gamma dose and internal dose due to the inhalation are also calculated in the model. Detailed mathematical descriptions LADAS may be seen in references (Suh, K.S. et al., 2009) .

NUMERICAL SIMULATIONS

LADAS on March 12, 2011 was operated to evaluate the radiological effects for the Fukushima accident. This model was connected with 3D meteorological forecasts from the KMA (Korea Meteorological Administration) at a resolution of 12 km in horizontal direction and 24 vertical levels. It was very difficult to estimate the concentrations of the radioactive materials released into the air on March 12 which was occurred in the explosion of Unit 1, because the source term information such as radionuclide, release rate and duration could not be known owing to the damage of the monitoring systems near the Fukushima power plant. Therefore, the source rates of ^{131}I and ^{137}Cs were assumed with the unit amount. On April 12, 2011, the Japan Atomic Energy Agency announced that the total amounts of ^{131}I and ^{137}Cs released into the atmosphere were 1.5 x 10^{17} and 1.3 x 10^{16} Bq, respectively. The time-varying source terms of ^{131}I and ^{137}Cs were presented in Figure 1(Chino, M. et al., 2011). A lots of radionuclides was transported to the Pacific Ocean from March 12 to April 6, but some was moved in the inland of Japan due to the variations of winds. Especially, ^{137}Cs was deposited on the ground due to aeolian fallout, mainly in the northwest direction from Fukushima. The calculated concentrations of ^{131}I in the air showed in Figure 2. In the early stage, the radioactive cloud moved to the north and east direction off Fukushima nuclear site and the cloud transported to the south and west direction after March 15, therefore inland of Japan was contaminated by the released radioactive materials. In general, lots of the radionuclides moved to Pacific Ocean from the Fukushima.

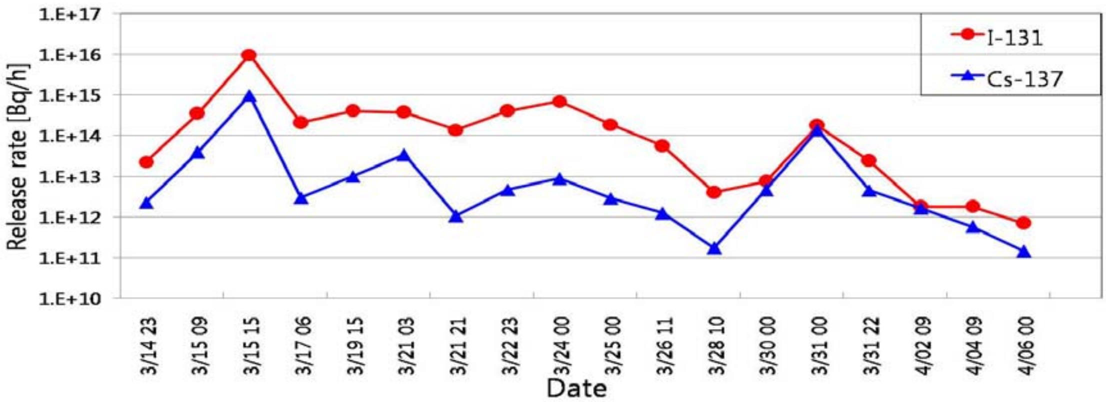

Figure 1. Time series of the source term for ^{131}I and ^{137}Cs.

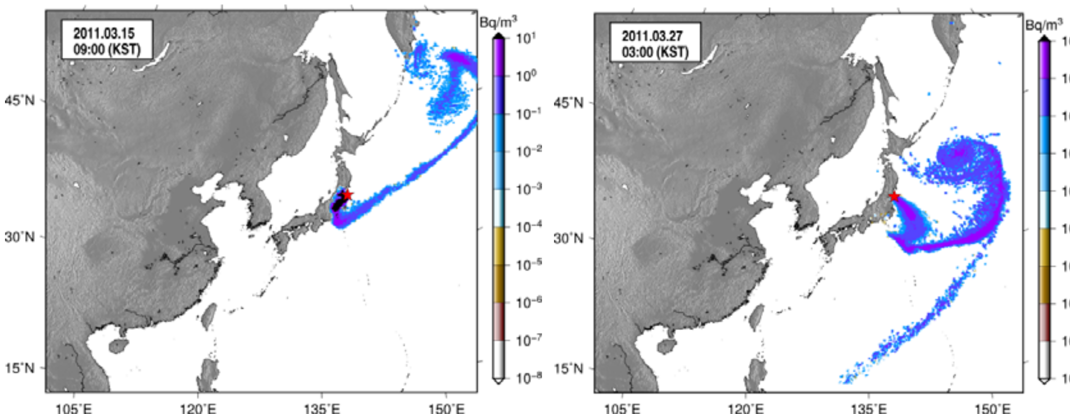

Figure 2. Calculated air concentration profiles of ^{131}I near a surface.

Atmospheric deposition of ^{137}Cs was also simulated to evaluate the radiological effects because of the long half life with 30.1 years. ^{137}Cs was mainly deposited in the northwest and south from March 12 to 31. The deposition rate was specially high in March 15 and March 30 due to rain episodes. Most of deposition occurred in a northwest area from Fukushima site. There is serious contaminated area until now. Calculated and measured deposition rates of ^{137}Cs were presented in Figure 3 and Figure 4, respectively. The simulation results were in good agreement with measurements.

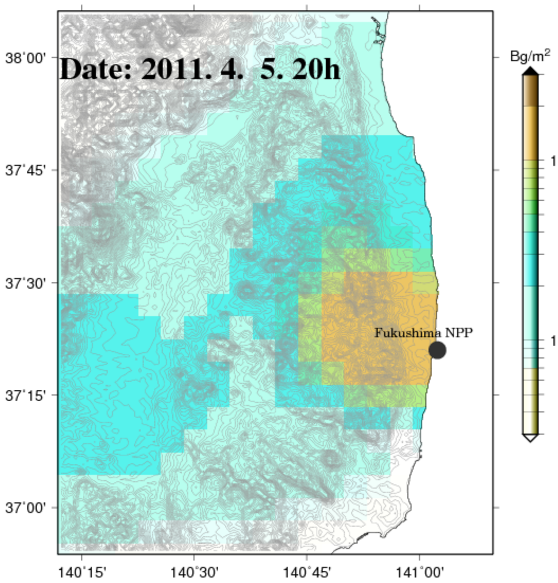

Figure 3. Concentrations of ^{137}Cs deposited on the surface.

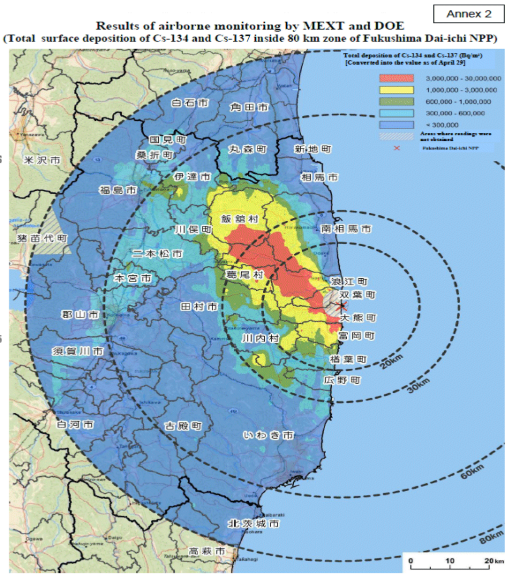

Figure 4. Measured deposition of ^{134}Cs and ^{137}Cs.

CONCLUSIONS

A three dimensional Lagrangian particle model was applied to evaluate the characteristics of atmospheric dispersion of the radionuclides released into the air from the Fukushima accident. The calculated results were compared with measurements. Lots of radionuclides moved to the Pacific Ocean, but some transported in the northwest area off Fukushima site. Especially, ^{137}Cs moved in the northwest part and deposited on the ground due to the light rain on March 15 and March 30. There are serious contaminated zone in the northwest of radius 20~30 km from Fukushima power plant. The simulation results are well reproduced in the contaminated area near the Fukushima site.

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