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Application of Source Detective System for a Fukushima Accident

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Introduction

A large amount of radionuclides was released into the air and sea by the Fukushima nuclear accident in 2011. Most of the radionuclides released into atmosphere were transported into the Pacific Ocean, but some were moved in land of Fukushima due to the wind. Atmospheric dispersion model was applied to evaluate the behavior of radionuclides released into the air from the accident, and the simulated concentrations of radionuclides were compared with the measurements in the air. The comparative results showed agreement between the simulations and measurements at some monitoring stations. Even though some radionuclides entered into the Korean Peninsula directly owing to the variations in wind during April 4 through 8, humans and the environment were not affected by the radiological impacts from the radioactive materials entering Korea.

Source Detective System

The source detective system has been developed to estimate the release information of radionuclides from measured data at monitoring stations. The system is mainly composed of three models: the trajectory, atmospheric dispersion, and source term estimation models.

- **Trajectory model**

$$\frac{dX}{dt} = V[X(t)]$$

Where, X is a position vector in a three-dimensional domain, t is a time, and V is a wind velocity vector.

- **Atmospheric dispersion model**

$$X_j(t+\Delta t) = X_j(t) + v_j(t)\Delta t + v_j'(t)\Delta t$$

The concentration in a particle tracking model can be obtained by counting the number of particles in an arbitrary control volume. The concentration is given by the number of particles divided by the volume of the grid.

$$C(x,y,z) = \frac{N_p}{\Delta x \Delta y \Delta z}$$

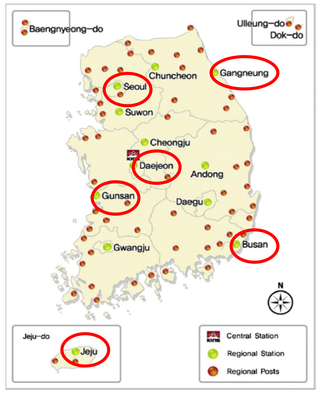
- **Source term estimation model**

$$S_i = \frac{M_i}{C_i}$$

where, S_i is the source term of pollutant (kg/h or Bq/h), M_i is the measured concentration (kg/m^3 or Bq/m^3), C_i is the dilution factor (h/m^3) which is equal to the calculated concentration under the assumption of unit release, and i is the radionuclide.

Numerical Simulations

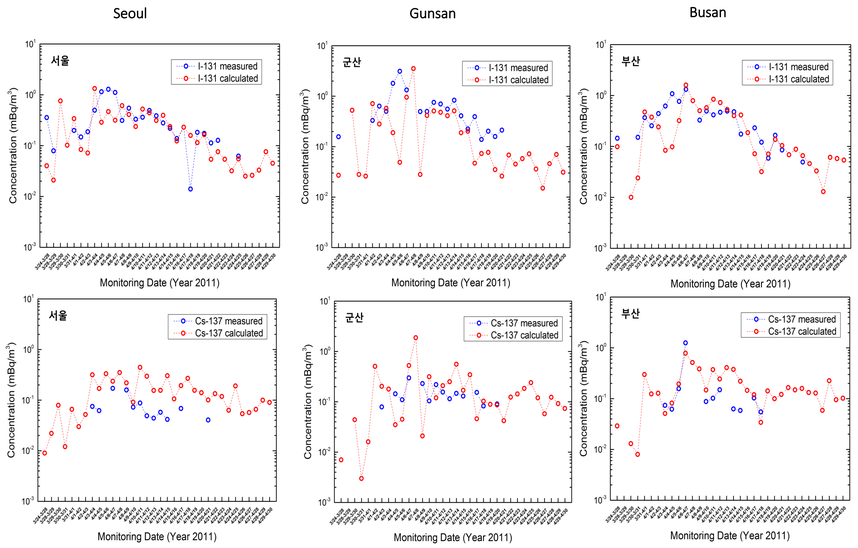
Relatively high concentrations of I-131 and Cs-137 were measured on 6 ~ 7 April at Gunsan and at Busan, respectively.



Basic input parameters

Meteorological data	KMA(Korea Meteorological Administration)
Model domain	12.21~52.89º N, 101.57 ~ 173.82 º E (regional) 90º S~90º N , 0 º ~360º E (global)
Horizontal resolution	12 km x 12 km (regional) 25 km x 25 km (global)
Simulation Period	2011.3.12.05h~ 2011.5.1.0h (KST)
Source terms of I-131 and Cs-137	Terada estimations (2012)
Release height	20 meters above ground
Diffusion Coefficients (Kx, Kz)	Kx = 2.5 x 10^4 m^2/sec, Kz = 1.0 m^2/sec
Dry deposition velocity	0.003 m/sec (I-131), 0.001 m/sec (Cs-137)
Wet deposition scheme	S=0.00005 x I$^{0.8}$ I=precipitation (mm/hr)
Output interval	3 hours

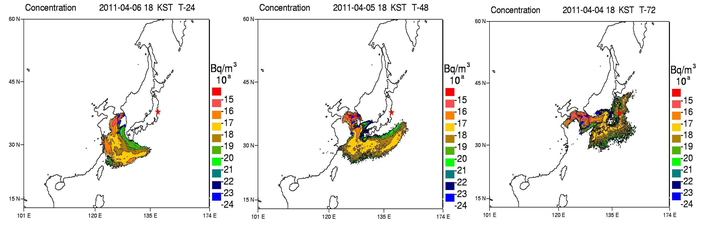
Comparison of calculated and measured concentrations



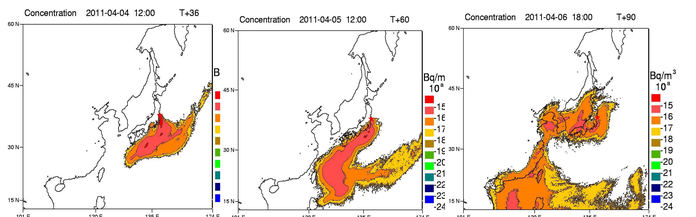
Evaluation of radionuclide pathway using measurements in Korea

♦ 6 locations (Seoul, Dajeon, Gunsan, Busan, Jeju, Gangneung) were used to estimate pathway of radionuclide from the Fukushima in the early of April. From the simulations, radionuclides released into the air from the Fukushima were transported directly from 3 to 5 April.

Backward simulations



Forward simulations



radionuclides	duration	Terada's estimation	In this study
I-131	2011.4.4 ~ 4.7	5 × 10^{13} Bq	3.6 × 10^{13} Bq
Cs-137	2011.4.4 ~ 4.7	1 × 10^{13} Bq	6.3 × 10^{12} Bq

♦ About 72 % of I-131 and 63% of Cs-137 of total amount released into the air was entered in Korea directly from April 4 to April 8, the other was moved to the Pacific Ocean.

Concluding Remarks

♦A source detective system has been developed to estimate the source region and release rates of radionuclides released into the atmosphere from a Fukushima accident. Simulated results were compared with measuremensts in some places. Comprative results had good agreements in some places, but they had little differences in some locations. About 72 % of I-131 and 63% of Cs-137 of total amount released into the air was entered in Korea directly from April 4 to April 8, the other was moved to the Pacific Ocean. The dose rates were 10^{-4} to 10^{-5} mSv/yr based on measuremets. Therforefore, humans and the environment were not affected by the radiological impacts from the radioactive materials entering Korea.

♦ Based on radionuclides measured at monitoring stations, the developed source detective system can be utilized as a tool for the evaluation of the characteristics of covert nuclear activities and unexpected nuclear accidents.

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