Long Range Atmospheric Dispersion Modeling

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1. Introduction

A study of the long range dispersion of the pollutants released into the atmosphere began to investigate the movements of the heavy metals and the effects of the acid rain since early 1970. Especially, the atmospheric dispersion models have been widely developed to predict and minimize the radiological damage for the surrounding environment after the TMI-2 and the Chernobyl accidents [1]. The intercomparison and validation study among the long range models were performed through the ATMES(Atmospheric Transport Model Evaluation Study) project under auspices of IAEA/WMO in 1992 [2].

Models for simulating the air concentration can be divided into two types such as the Eulerian and Lagrangian. Eulerian models are based on the solution of time-dependent advection–dispersion equation. The concentrations in Lagrangian models are calculated by tracking the trajectory of Lagrangian particle. In this study, the characteristics of the above models are represented and test simulation using Lagrangian model is performed.

2. Eulerian Model

The air concentrations in Eulerian model are calculated by solving the advection-dispersion equation in fixed coordinates. The Eulerian models are easy to connect to the wind field models because they have the same grid systems with wind field models. Also, the diffusion coefficients of horizontal and vertical are independently determined regardless of atmospheric stability. But the numerical diffusion induce in the case of the rapid concentration gradient near a source point and the specification of the boundary conditions is not easy. The advection-dispersion equation in this model is as follows.

$$\frac{\partial c}{\partial t} = -V\nabla c + \nabla K \nabla c + E - R \tag{1}$$

Where, c is the air concentration, V is the wind vector, K is the diffusion coefficients, E is the emission and R is the removal function.

3. Lagrangian Model

The particle to depict the characteristics of pollutant in Lagrangian type model can be released to evaluate the transport and diffusion process of pollutant in atmosphere. The concentration is calculated by tracking the trajectory of Lagrangian particle. Lagrangian models can treat the rapid concentration gradient near a source point easily and don't also cause the numerical diffusion. The particle is advected by the averaged wind components and dispersed by turbulent motion in three dimensional space. The movement of the particle is represented by the sum of the movements due to the advection and the turbulence. The new position of a particle after time step Δt is represented as follows.

$$X_j(t+\Delta t) = X_j(t) + v_j(t)\Delta t + v_j'(t)\Delta t \tag{2}$$

Where v_j are the averaged wind components(j=1,2,3) and v_j' are turbulent components of wind (j=1,2,3).

The concentration in Lagrangian particle model is calculated in the domain of interest by counting the number of particles in arbitrary control volume. The concentration is equal to the number of particles divided by volume of the box.

4. Application of Lagrangian Model

The wind patterns are the one of the most important parameters in the operation of the dispersion model. The meteorological prediction data in the region of Northeast Asia are produced using the mesoscale weather forecast numerical model named MM5[3] at KMA(Korea Meteorological Administration) in Korea. The computational area covered extends from 102.47° E to 173.34° E and from 12.27° N to 53.72° N. The spatial resolution is about 30 km and the grids are composed of 190 x 170 pints in horizontal direction. The vertical coordinate system has the 25 levels from 1001 hPa to 50 hPa. The meteorological data are produced with 3 hours time interval on twice a day. The archived data is the wind component, temperature, humidity, geopotential height, precipitation and others.

The test simulation using Lagrangian model was performed to check the connection system of the meteorological data and to investigate the physical aspects of basic parameters in dispersion model. The computational domain and grid system in dispersion model were the same with the them of the meteorological model. The release point of Cs-137 assumed in the east part of the China. The total release amount of Cs-137 assumed about 10^4 TBq and the release duration was about 24 hours. The released height considered about 50 m from surface. The horizontal and vertical diffusion coefficients were set with 4.5 x 10^4 m^2/s and 1 m^2/s in the whole computational domain respectively. The calculation was performed from 24:00 GMT on 5 January to 00:00 GMT on 9 January 2002. The predicted wind and the calculated concentration profile using the basic meteorological data are represented in Fig. 1 and Fig. 2 respectively. The computed concentrations are mainly advected toward the southeast part of release point by the wind fields and dispersed widely by horizontal diffusivity. From the predicted wind patterns, the wind vector showed the predominant movements of the south-west direction from the release point until 12 hours after release. After that, the wind patterns were changed to the north-west direction. It inferred that the radionuclides moved from the south part of Taiwan to south part of Japan. From the computed concentration profiles, the radioactive cloud moved along the east coast of China at the initial stage and spread the west coast of Japan. After that, the cloud moved toward Taiwan by the strong north-west wind and gradually moved to the south-east part of coast of Japan by the south-west wind.

The radioactive cloud expanded in the south part of Japan after 45 hours from release.

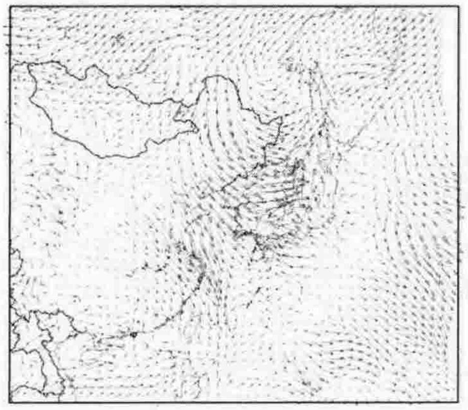

Fig. 1. The predicted wind profiles.

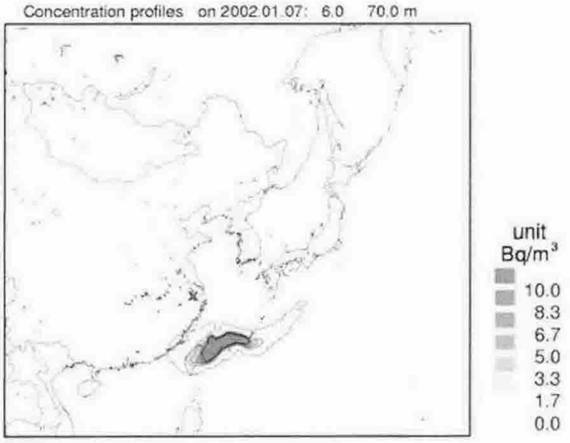

Fig. 2. The calculated concentration profiles.

5. Conclusion

Lagrangian particle model was applied to evaluate the characteristics of the long range atmospheric dispersion. The weather forecast data are the one of the most important parameters to calculate the concentration in long range dispersion model. The simulation was performed to check the connection system of the meteorological data and to investigate the physical aspects of basic parameters in dispersion model. The calculated concentrations are mainly advected toward the south-east part of release point by the wind fields and dispersed widely by horizontal diffusivity. The developed Lagrangian particle model for long range atmospheric dispersion will be provided as a basic tool to evaluate the atmospheric diffusion and the radiological dose assessment in the national emergency preparedness system [4].

REFERENCES

[1] W. Klug, G. Graziani, G. Grippa, D. Pierce, and C. Tassone, Evaluation of Long Range Atmospheric Transport Models using Environmental Radioactivity Data from the Chernobyl Accident, Elservier Applied Science, London and New York, 1992.

[2] S. Mosca, R. Bianconi, R. Bellasio, G. Graziani, and W. Klug, ATMESII-Evaluation of long-range dispersion models using data of the 1st ETEX release, Joint Research Center, 1998.

[3] G.A. Grell, J. Dudhia, and D.R. Stauffer, A description of the fifth-generation Penn State/NCAR mesoscale model MM5, NCAR/TN-398, 1995.

[4] J.W. Cho, K.W. Nam, I.Y. Chun, et al., Development and operation of the network system for nuclear safety. KINS/AR-704, 1999 (in Korean).