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Session3 Behavior of Radioactivity

4.16 AN EVALUATION OF DRY DEPOSITION FROM THE LONG RANGE ATMOSPHERIC DISPERSION

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ABSTRACT

The dry deposition of pollutants released into the atmosphere must be evaluated to estimate the radiological dose of terrestrial plants and foodstuffs in the ecosystem. Especially, the atmospheric dispersion and dry deposition models have been widely developed to predict and minimize the radiological damage for the surrounding environment after the TMI-2 and the Chernobyl accidents. A Lagrangian particle model for the evaluation the long-range dispersion has been firstly developed in Korea since 2001. The particle tracking method was used for the estimation of the concentration distribution of the radioactive materials released into the atmosphere. The model is designed to estimate air concentration and ground deposition at distances up to some thousands of kilometers from the source point in the horizontal direction. The turbulent motion is considered to separate the treatment of particles within the mixing layer and above the mixing layer. Also, the dispersion model is designed to receive the results of the MM5 model being operated by KMA(Korea Meteorological Administration). The test run of the long-range dispersion model has been performed in the area which covered extends from 102.47° E to 173.34° E and from 12.27° N to 53.72° N in Northeast Asia. The release point of Cs-137 assumed in the east part of the China. The long range dispersion model has been firstly developed to estimate the radiological consequences against a nuclear accident. The model will be supplemented by the comparative study using the data of the ETEX experiments.

KEYWORDS : long range, atmospheric dispersion, dry deposition, radiological consequences

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].

The extent of the local scale dispersion model is considered up to a few hundred kilometers in horizontal scale and within the mixing height in vertical scale. In contrast with the local scale model, the computational domain of long range dispersion model can be considered with synoptic scale from a few hundred kilometers to a few thousands kilometers in horizontal scale and from surface to troposphere in vertical scale.

The dry deposition is an important removal process for some atmospheric pollutants. The uptake of the pollutants at the earth's surface, either by soil, water and vegetation, reduces airborne concentration levels at locations a far distance, while potentially increasing exposure levels at nearby locations due to the deposition material. The dry deposition flux of pollutants to the surface is calculated from the product of the dry deposition velocity and the atmospheric dispersion model to predict airborne concentrations. So it is important to obtain the accurate evaluation of airborne concentration in a dispersion model to estimate the flux of dry deposition on the surface.

There are many nuclear power plants in the region of Northeast Asia. It is necessary to develop a long range atmospheric dispersion model for the radiological emergency preparedness against a nuclear accident. From this viewpoint, a Lagrangian particle model for the evaluation the long range dispersion was initially developed in Korea since 2001. The Monte Carlo method was used for the estimation of the concentration distribution of radioactive materials released into the atmosphere. The model designed to estimate air concentrations and dry deposition as well as wet deposition at distances up to some 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 above the mixing layer. Also, the wind field in the dispersion model is designed to receive the results of the MM5 model[3] being operated by KMA(Korea Meteorological Administration). The dry deposition velocity for each radionuclide is introduced to calculate the flux of dry deposition in the dispersion model.

2. METEOROLOGICAL DATA

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, mixing height, heat flux, surface pressure and others.

3. LONG RANGE DISPERSION 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 type models can treat the rapid concentration gradient near a source point easily and don't also cause the numerical dispersion.

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.

$$X_j(t+\Delta t) = X_j(t) + v_j(t)\Delta t + v_j'(t)\Delta t \tag{1}$$

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

The horizontal displacement due to turbulence is computed by:

$$v_j'(t)\Delta t = \sqrt{2K_j\Delta t}R \tag{2}$$

Where K_j (j=1,2) are the horizontal diffusion coefficients and R is random numbers picked up from a Gaussian distribution having mean value and standard deviation equal to 0 to 1 respectively[4]. To calculate the vertical component of $v_3'(t)\Delta t$, two situations have been distinguished like within mixing layer and above mixing layer [4].

$$v_3'(t)\Delta t = \sqrt{2K_3\Delta t}R \quad \text{(above mixing layer)}$$

$$v_3'(t)\Delta t = (h_{pbl} - Z_g)R \quad \text{(within mixing layer)} \tag{3}$$

Where K_3 is the vertical diffusion coefficient, h_{pbl} is the mixing height and Z_g is the height of the topography.

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. If the control volume has dimension Δx, Δy, Δz and contains N_p number of particles, then the air concentration *c(x,y,z)* at center of the box may be computed as follows.

$$c(x,y,z) = \frac{N_p}{\Delta x \Delta y \Delta z} \tag{4}$$

Dry deposition is calculated over the same grid of air concentration and accumulated over each time step as time integrated air concentration. At each time step, the increment in deposited amount on ground is given by:

$$c(t+\Delta t)_{dry} = c(t)[1 - \exp(\frac{-v_d \Delta t}{h_{pbl}})] \tag{5}$$

Where v_d is the deposition velocity of each pollutant and it considers with an averaged value. Wet deposition depends on the rainfall intensity and it is given by:

$$c(t+\Delta t)_{wet} = c(t)[1-\exp(-\Lambda \Delta t)] \qquad (6)$$

Where Λ is the scavenging coefficient.

4. TEST RESULTS

The test run was performed to check the connection system of the meteorological data and to investigate the physical aspects of basic parameters in dispersion model. The simulation of the long range dispersion model was performed in the area which covered extends from 102.47° E to 173.34° E and from 12.27° N to 53.72° N in Northeast Asia. The grid system in dispersion model was the same with the one 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 profiles using the basic meteorological data are represented in Fig. 1, Fig. 2 and Fig. 3 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 west-south direction from the release point until 12 hours after release. It inferred that the radionuclides moved from the south part of Taiwan to south part of Japan, because the wind of the west-south direction blew up to the south part of Japan on 6 January to 18:00 GMT. 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.

5. CONCLUSION

A three dimensional Lagrangian particle model was developed to evaluate the characteristics of the long range atmospheric dispersion. The developed Lagrangian particle model is effective tool to simulate the atmospheric dispersion of airborne pollutants. The weather forecast data are the one of the most important parameters to calculate the concentration in long range dispersion model. The calculated concentrations are mainly advected toward the southeast part of release point by the wind fields and dispersed widely by horizontal diffusivity.

The developed long range model will be utilized as a basic tool to evaluate the atmospheric diffusion and the radiological dose assessment in the national emergency preparedness system named

CARE(Computerized technical Advisory system for the Radiological Emergency preparedness)[5]. And then, the particle model will be modified by the comparative study using the data of the ETEX experiments[6].

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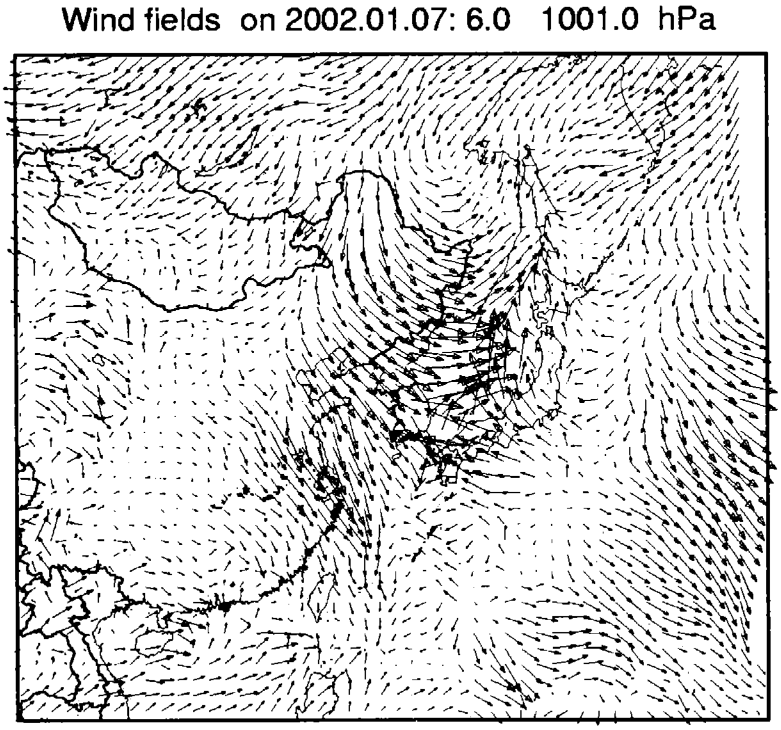
REFERENCES

1. Klug, W., Graziani, G., Grippa, G., Pierce, D. and Tassone, C., Evaluation of Long Range Atmospheric Transport Models using Environmental Radioactivity Data from the Chernobyl Accident, Elservier Applied Science, London and New York (1992).
2. Mosca, S., Bianconi, R., Bellasio, R., Graziani, G. and Klug, W., ATMESII-Evaluation of long-range dispersion models using data of the 1st ETEX release, Joint Research Center (1998).
3. Grell, G.A., Dudhia, J. and Stauffer, D.R., A description of the fifth-generation Penn State/NCAR mesoscale model MM5, NCAR/TN-398 (1995).
4. Anfossi, D., Sacchetti, D. and Catelli, S.T., Development and sensitivity analysis of a Lagrangian particle model for long range dispersion, *Environmental Software,* **10(4)**, 263-287 (1995).
5. Cho, J.W., Nam, K.W., Chun I.Y., et al., Development and operation of the network system for nuclear safety. KINS/AR-704 (1999) (in Korean).
6. European Commission, The European Tracer Experiment, Joint Res. Center, EUR 18143 EN (1998).



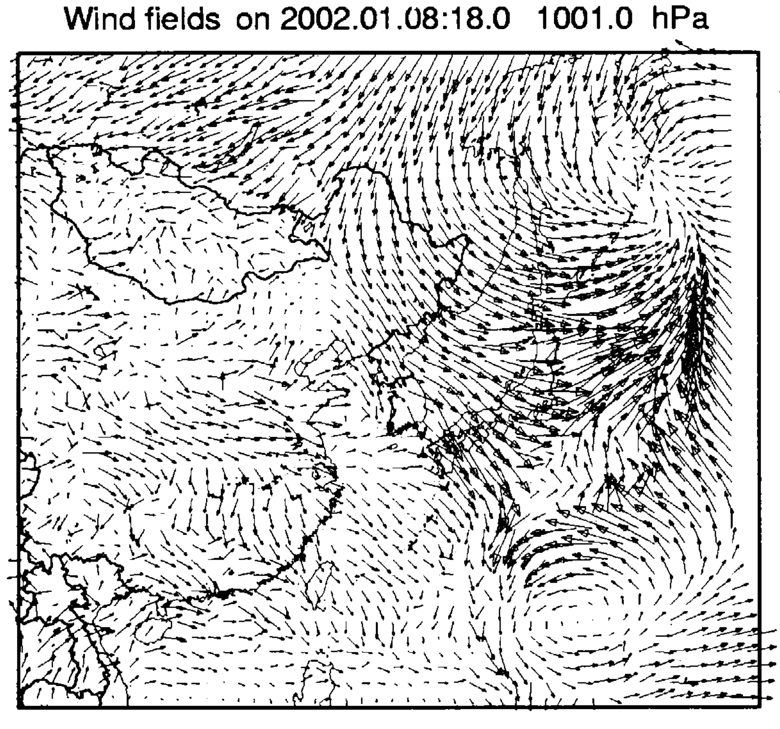


Fig. 1. The predicted wind profiles in the region of Northeast Asia.

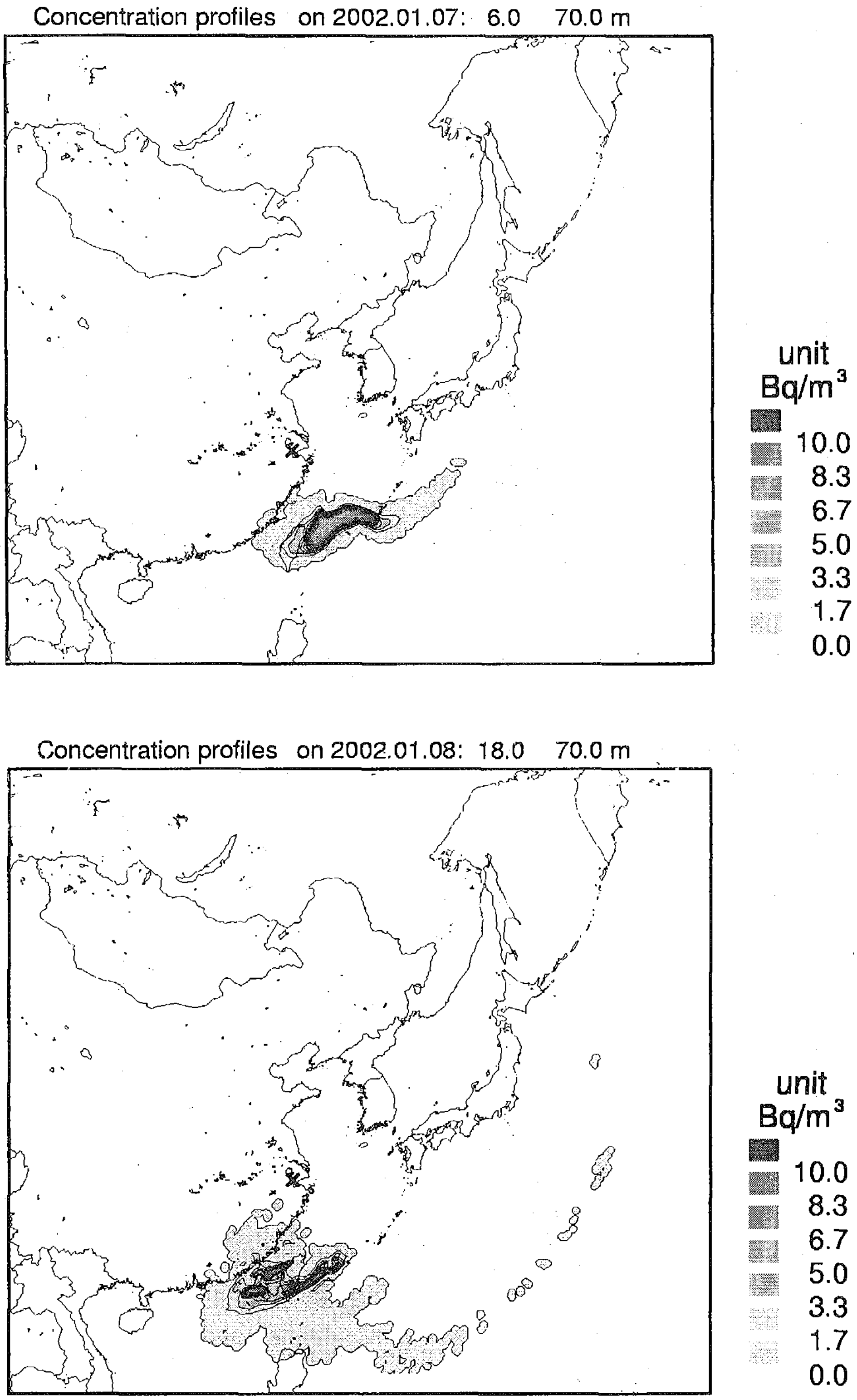
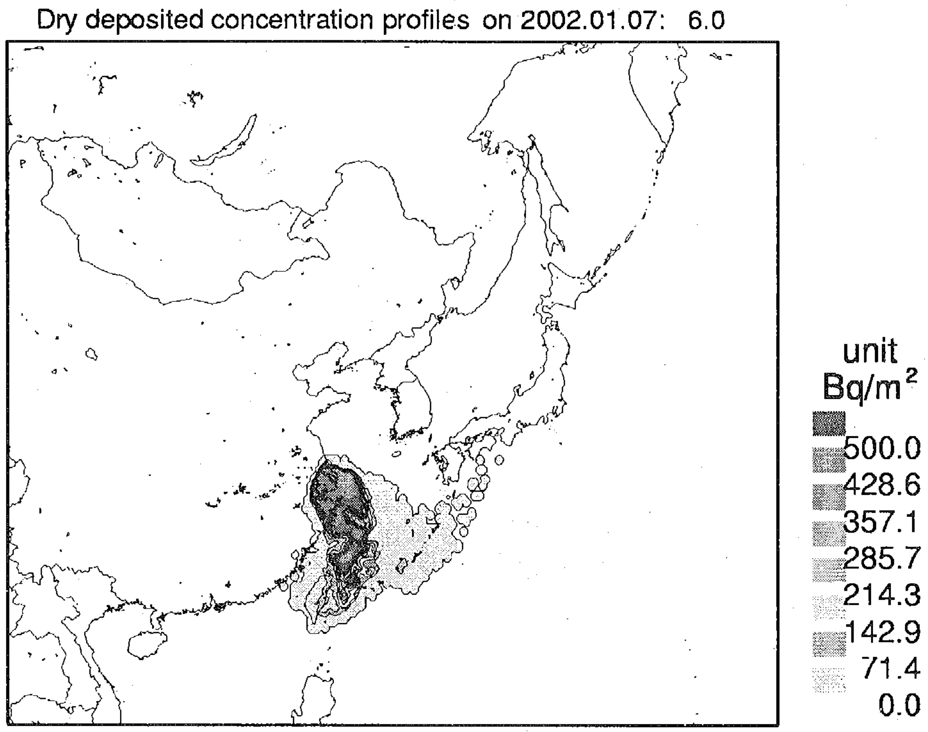


Fig. 2. The calculated air concentration profiles in the region of Northeast Asia.



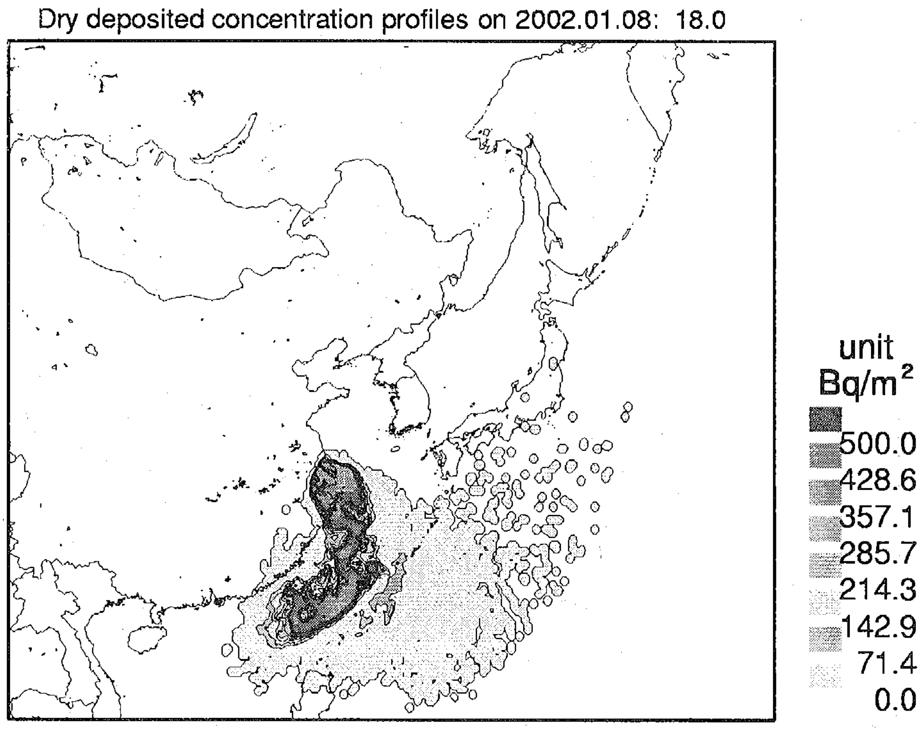


Fig. 3. The dry deposited concentration profiles in the region of Northeast Asia.