Long-Range Atmospheric Tracer Experiment

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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. 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 named LADAS(Long-range Accident Dose Assessment System)[1] was initially developed for the evaluation the long-range dispersion in Korea since 2001.

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]. As a consequence of ATMES, it was observed that in a real emergency case, under conditions of urgency and stress, many models would have had different results. So, one of the main recommendations was the launch of a long-range atmospheric tracer experiment (ETEX) in conditions as close as possible to those which could be found in a real emergency case, with the advantage of complete knowledge of the source term.

2. European Tracer Experiment (ETEX)

The members of the ATMES steering committee were proposed that a tracer experiment in Europe should be performed to complement the weakness of ATMES. The experiment was named ETEX, European Tracer Experiment [3]. It was designed to test the readiness of interested services to respond in the case of an emergency, to organize the tracer release and compile a data set of measured air concentrations and to investigate the performance of long-range atmospheric transport and dispersion models using that data set.

ETEX essentially consisted of two releases to atmosphere of tracers(perfluorocarbons) sampled for three days after the beginning of the emission using a sampling network spread over a large part of Europe. When the two releases took place, about 30 modelling research groups all over the world were informed of the time, location and characteristics of the release and predicted in real-time the dispersion patterns of the tracer over the subsequent 60 hours. The model predictions were sent to the reference center at JRC Ispra (Italy), where they ere analyzed and collated for subsequent evaluation. The real-time transmission of model results was useful for evaluating their capability to respond in an emergency by making such information available to decision makers.

The sampling network consisted of 168 ground-level sampling stations in Western and Eastern Europe. Each station was labeled with one or two letters identifying the country where it was located and numbered sequentially. The sampling stations and release point are shown in Fig. 1. To complement the meteorological measurements routinely gathered by the WMO network all over Europe, additional ground level and upper-air meteorological measurements at the release site were performed to obtain a comprehensive meteorological database. The perfluorocarbons (PFCs) are selected with the tracer gas. PFCs are environmentally safe, non-toxic, not washed out by rain and allow extremely high analytical detection sensitivity due to the very low atmospheric background levels as confirmed by extensive preliminary assessments. The mass released and release rate were chosen so that expected concentration values, even at the most distant sampler could be high enough relative to normal background levels to ensure successful chemical analysis.

The first release started at 1600 UTC on October 23, 1994 and lasted 11 hours and 50 minutes. 340 kg of PMCH (perfluoromethycyclohexane) were released in Montefil at an average flow rate of 8.0 g/s. A SODAR was operating at the release site during the first experiment. Vertical profiles of horizontal wind speed and direction and vertical wind speed were measured from 30 to 600 m above ground. During the release the wind blew between 240 and 290 degrees, i.e. from west-south west to west-north west. The wind was westerly at the start of the release with a tendency to be from wet-north west until midnight and from west-south west at the end of the release. The wind direction changed between south and west during the rest of the period. The wind speed during the release ranged between 4 and 7 m/s. During the first release each of the 168 sampling stations collected 24 samples which accounts for a total of more than 4000 samples. All tubes were sent to the JRC Ispra for chemical analysis. The detailed results of all analyses are collected in the ETEX data base. All the data consist of 3 hour average concentrations available at each site for 96 hours from the time

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The reconstruction of the cloud position and shape from the measurements revealed that even the relatively uncomplicated meteorological conditions of westerly winds that frequently occur in Europe produced unexpected cloud behavior following the release of 23 October. A north west-south east cloud elongation was observed to occur 48 hours after the release start in a direction approximately 60° to that of transport. The concentration profiles at the 48 hours after the release are shown in Fig. 2.

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 model 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.

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

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.

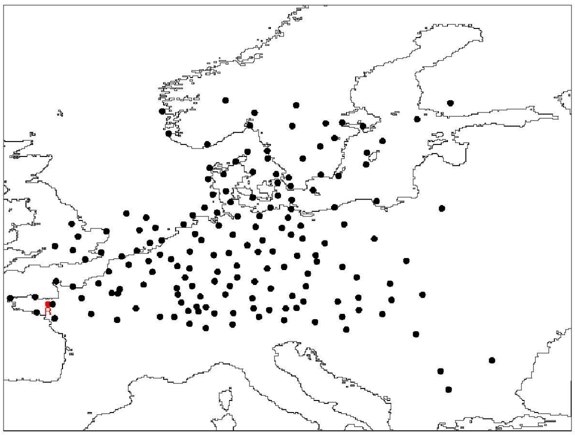

Fig. 1. The release point and sampling network.

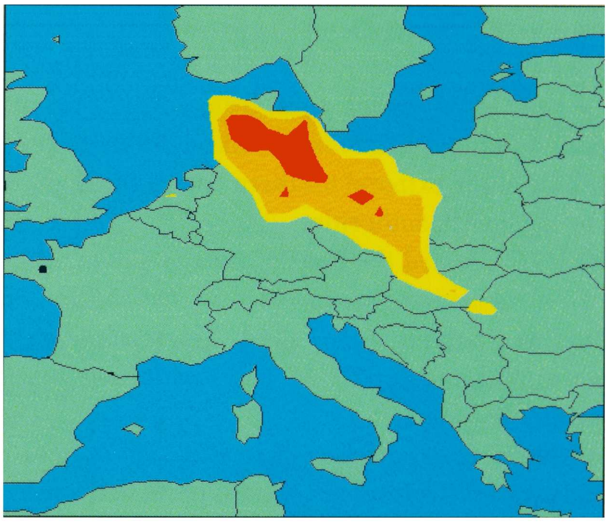

Fig. 1. The cloud contour at the 48 hours.

4. Conclusion

The long-range atmospheric transport model named LADAS have been developed and applied to evaluate the characteristics of the long-range atmospheric dispersion. The data of the long-range tracer experiment named ETEX were gathered and analyzed to validate the long-range transport model. The weather forecast data are the one of the most important parameters to calculate the concentration in long-range dispersion model. The meteorological data with 6 hours time interval are supplied by ECMWF. 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 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.

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