4.7 Atmospheric Transport Model

4.7.1 Introduction

Since the 1st July 1997, JMA has been a Regional Specialized Meteorological Centre (RSMC) with the specialization to provide atmospheric transport model products for environmental emergency response, with responsibility for the WMO Regional Association II. RSMC Tokyo is required to provide advice on the atmospheric transport of pollutants related to nuclear facility accidents and radiological emergencies. The RSMC's atmospheric transport model products are sent to the National Meteorological Service (NMS) of the WMO Member State.

4.7.2 Model

(a) Basic framework

The atmospheric transport model follows a Lagrangian approach, where many tracer particles are released at the time and location of pollutant emissions, displaced due to horizontal and vertical advection and diffusion, and dropped through dry and wet deposition. The advection, diffusion and deposition are computed with 3-hourly outputs from the operational global NWP model. The horizontal and vertical displacements during 1 time step δt are given as follows:

$$\delta x = u\,\delta t + G\{(2k_{hor}\,\delta t)^{1/2}\} \tag{4.7.1}$$

$$\delta y = v\,\delta t + G\{(2k_{hor}\,\delta t)^{1/2}\} \tag{4.7.2}$$

$$\delta z = w\,\delta t + \Sigma G\{(2K\,\delta t')^{1/2}\} \tag{4.7.3}$$

where *G*'s are random displacements whose statistical distributions take the Gaussian distribution functions with standard deviations indicated in parentheses. Tracer particles are removed from the atmosphere due to dry and wet deposition and radioactive decay.

(b) Vertical and horizontal diffusion

Assuming a random walk model, the probability density of displacement associated with vertical diffusions becomes a Gaussian distribution with a standard deviation of $(2K\delta t')^{1/2}$. A Monte Carlo method is used to determine displacement of each tracer particle so that it results in a Gaussian distribution. The time step $\delta t'$ is much less than that for advection. Vertical diffusion coefficients have fine vertical structures dependent on model levels. By taking a shorter time step, vertical displacements due to diffusion are kept smaller than the thickness of the model layer.

The vertical diffusion coefficient K is derived from meteorological parameters on the model η-levels in the analogue with molecular diffusion coefficient following Louis et al. (1981). The vertical diffusion coefficient is given as follows:

$$K = l^2 \left| \frac{\partial v}{\partial z} \right| F(Ri) \qquad (4.7.4)$$

where the parameters l and Ri are the vertical mixing length of turbulence and the Flux Richardson number, respectively. The similarity function of $F(Ri)$ is taken from Louis et al. (1981). The mixing length is written as a function of geometric height z

$$l = \frac{kz}{1 + kz / l_0} \qquad (4.7.5)$$

where k is the von Kármán's constant and l_0 is the maximum mixing length.

The displacement of each tracer due to horizontal diffusion is handled with a Monte Carlo method based on a random walk model similarly to the vertical diffusion. In this case, the probability density of displacement is set to be the Gaussian distribution function with the standard deviation of $(2k_{hor}\delta t)^{1/2}$. The horizontal diffusion coefficient k_{hor} should be parameterized considering the model resolution and temporal and spatial variations of meteorological fields. But an appropriate constant value is set in the model to save computational time.

(c) Dry and wet deposition

The surface tracer flux F due to dry deposition is presented by means of the deposition velocity $V(z_r)$ and concentration $C(z_r)$ at a reference level z_r as

$$F \equiv V(z_r)C(z_r) \qquad (4.7.6)$$

For simplicity, the deposition rate is set to F/z_r.

Concerning wet deposition, only wash-out processes are parameterized. The wet deposition rate is approximated as a function of precipitation intensity P(mmh^{-1}) predicted by the dynamical model with the scavenging ratio per hour given by

$$A \approx 0.1 \times P^{0.75} \tag{4.7.7}$$

according to Kitada (1994).

A Monte Carlo method is used to remove tracer particles from the atmosphere at the above-mentioned dry and wet deposition rates.

4.7.3 Products

The atmospheric transport model products are the charts of 3D trajectories, time integrated pollutant concentrations and total deposition. Sample charts are shown in Fig. 4.7.1-4.7.5.

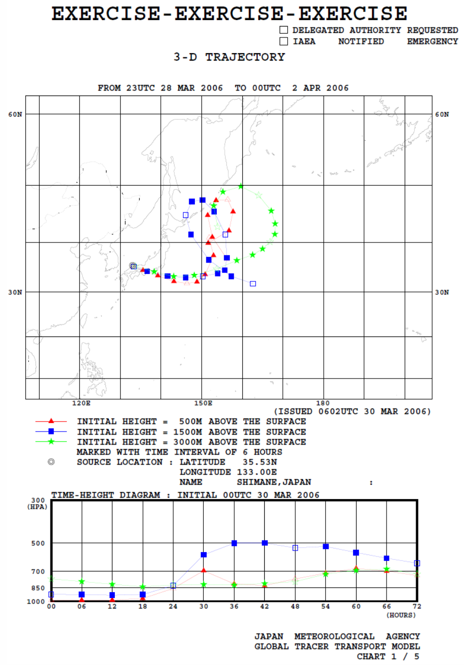

Fig. 4.7.1 An example of the 3D trajectories

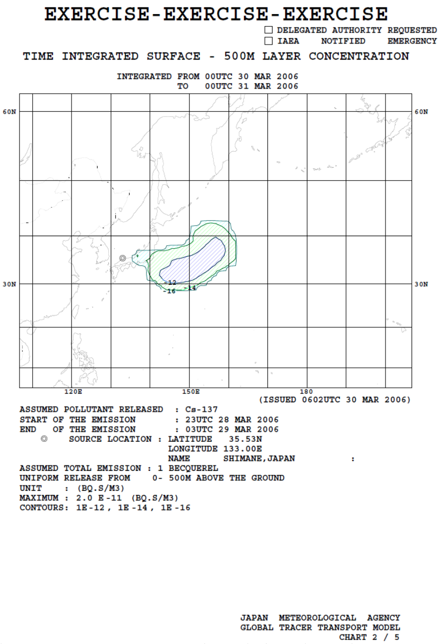

Fig. 4.7.2 An example of the time integrated concentration up to 24 hours forecast

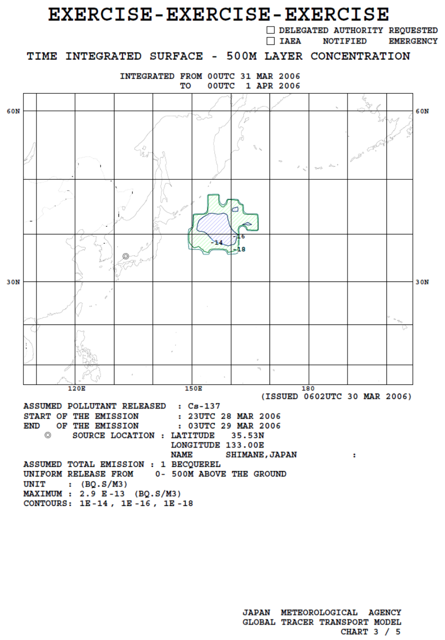

Fig. 4.7.3 An example of the time integrated concentration up to 48 hours forecast

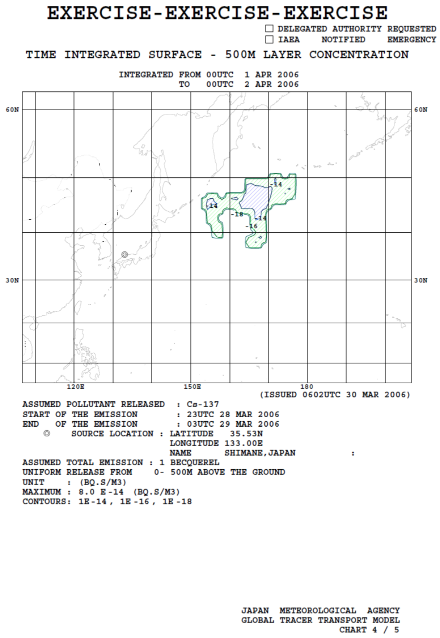

Fig. 4.7.4 An example of the time integrated concentration up to 72 hours forecast

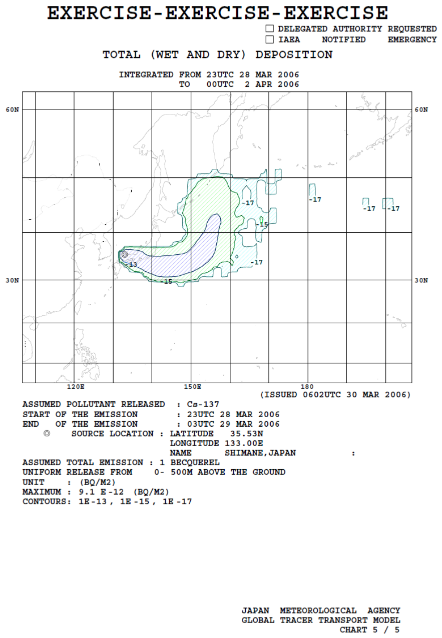

Fig. 4.7.5 An example of the total deposition

References

Kitada, T., 1994: Modelling of transport, reaction and deposition of acid rain, *Kishou Kenkyu Note*, **182,** 95–117. (in Japanese)

Louis, J.F., M. Tiedtke, and J.F. Geleyn, 1981: A short history of the operational PBL-parameterization at ECMWF, Workshop on Planetary Boundary Layer Parameterization 25-27 Nov. 1981, 59–79.