RSMC TOKYO
USERS' INTERPRETATION GUIDELINES
ATMOSPHERIC TRANSPORT MODEL OUTPUTS

Oct. 2016

1. Introduction

In July 1997, the Japan Meteorological Agency (JMA) was designated by the World Meteorological Organization (WMO) as a Regional Specialized Meteorological Centre (RSMC) supporting environmental emergency response (EER) activities. RSMC Tokyo is responsible for providing atmospheric transport and dispersion modelling (ATDM) products in response to requests from the International Atomic Energy Agency (IAEA) and Members of the WMO Regional Association II (RA II). In such work, the centre responds jointly with RSMCs Beijing and Obninsk.

2. The Numerical Weather Prediction System and Atmospheric Transport/Dispersion Model Used for the Service

2.1 Global Numerical Weather Prediction System

The ATDM adopted by RSMC Tokyo involves the use of the Lagrangian approach, in which tracer particles released at the temporal and spatial points of pollutant emission are displaced due to horizontal and vertical advection and diffusion and laid down through dry and wet deposition. Computation of this advection, diffusion and deposition is based on operational forecasting using a global numerical weather prediction (NWP) model called the Global Spectral Model (GSM), whose specifications are shown in Table 1.

Table 1 Global Numerical Weather Prediction System used by RSMC Tokyo

Forecast model	
Horizontal resolution	Truncated linear grid (TL) with a total wave number of 959 (grid interval: 0.1875 deg/20 km)
Vertical layers	100 sigma/pressure hybrid levels up to 0.01 hPa
Forecast Initial (analysis) times	0000, 0600, 1200, 1800 UTC
Forecast lengths	84 hours (3.5 days) at 0000, 0600, 1800 UTC 264 hours (11 days) at 1200 UTC
Data assimilation	
Assimilation method	4 DVAR
Horizontal resolution	Forward model: TL 959 (grid interval: 0.1875 deg/20 km) Adjoint model: TL 319 (grid interval: 0.5625 deg/55 km)
Vertical layers	As per the Forecast Model

High-resolution grid point data are not necessarily suitable for the ATDM, as rapid response is required for operational emergency response action and long-term data accumulation is needed for past release scenarios[1]. Assimilation data for all initial times are

[1] The term "past release" refers to cases in which tracer release starts before the NWP initial time. This is in contrast to the term "future release," in which release starts after the initial time.

reduced to TL319L40 (0.5625 deg/55 km, 40 hybrid levels) and accumulated to allow timely provision of operational services to users. It should be noted that the operational ATDM starts only at the nearest synoptic time (0000 or 1200 UTC) as prescribed in Appendix II-7 of the Manual on the GDPFS (WMO 2010).

2.2 Atmospheric Transport and Dispersion Model

The ATDM used by RSMC Tokyo is based on Iwasaki et al. (1998) with some modifications developed by Kawai (2002). Advection, diffusion and deposition are computed using three-hourly model-level outputs with temporal and spatial interpolation to tracer points. A total of 1,000,000 tracer particles are used in the operational ATDM, and time-integrated concentration and deposition are calculated using 0.5×0.5-degree latitude-longitude grids.

2.2.1 Horizontal and Vertical Diffusion

Horizontal velocities of tracers are estimated in accordance with Gifford (1982) as

$$u = R_h u_m + \sqrt{\left(1 - {R_h}^2\right)}\, \sigma G \,, \tag{1}$$

$$v = R_h v_m + \sqrt{\left(1 - {R_h}^2\right)} \sigma G, \tag{2}$$

where u and v are zonal and meridional wind speed components, and u_m and v_m are those forecast using the global numerical weather prediction system. R_h is an autocorrelation of Lagrangian velocity as estimated using $e^{\delta t/T_L}$, where δt is the single time step length and T_L is the Lagrangian time scale. σ is the root mean square of horizontal velocity, which can be estimated as $(K/T_L)^{1/2}$ with reference to eddy diffusivity K. G represents a random fluctuation whose statistical distribution exhibits a Gaussian distribution function with a mean of 0 and a standard deviation of 1. The Monte Carlo method is used to determine velocities and displacements of individual tracer particles.

The vertical displacement for a single time step δt is given as

$$\delta z = w\, \delta t + \sum G \sqrt{2 k_v \delta t'} \tag{3}$$

The vertical diffusion coefficient depends on atmospheric vertical profiles. The time step for the integration of vertical diffusion $\delta t'$ is much shorter than those for the integration of horizontal diffusion and advection. This shorter time step is used so that vertical displacement due to diffusion does not exceed the thickness of the model layer. The vertical diffusion coefficient k_v is set with reference to meteorological parameters processed by the NWP model in a way analogous to the molecular diffusion coefficient estimation of Louis et al. (1982), and is given as follows:

$$k_v = l^2 \left|\partial v / \partial z\right| F_{(R_i)}, \tag{4}$$

where the parameters l and R_i are the vertical mixing length of turbulence and the flux Richardson number, respectively. The similarity function of $F_{(R_i)}$ is defined with reference to Louis et al. (1982). The mixing length is written as a function of the geometric height z:

$$l = kz / (1 + kz/l_0), \quad (5)$$

where k is the von Karman constant and l_0 is the maximum mixing length. The horizontal diffusion coefficient k_{hor} should be parameterized in consideration of the model resolution and the temporal and spatial variations of meteorological fields. An appropriate constant value is set to save computational time.

2.2.2 Dry and Wet Deposition

The surface tracer flux F caused by dry deposition is presented using the deposition velocity $V_{(Z_r)}$ and concentration $C_{(Z_r)}$ at the reference level Z_r as

$$F = V_{(Z_r)} C_{(Z_r)}. \quad (6)$$

For simplicity, the deposition rate is set to F/Z_r with reference to Kitada et al. (1986).

For wet deposition, only wash-out processes are parameterized. The wet deposition rate A is approximated as a function of precipitation intensity P predicted by the meteorological model (GSM) with the below-cloud scavenging ratio per hour given by Kitada (1994) as

$$\mathrm{A} \cong 0.1 \times P^{0.75}. \quad (7)$$

The Monte Carlo method is applied to decide which tracer particles are removed from the atmosphere at the above-mentioned dry and wet deposition rates.

It should be noted that noble gases such as ^{133}Xe are exceptions for these depositing treatments.

2.2.3 Radioactive Decay

Table 2 lists radioactive species relevant to the ATMD at RSMC Tokyo. If users specify materials other than those in the table above, a default value of ^{137}Cs will be used to estimate radioactive decay.

Table 2 Radioactive species applicable to RSMC Tokyo's ATDM

Noble gas (non-depositing)	^{85}Kr, ^{133}Xe
Depositing species	^{89}Sr, ^{90}Sr, ^{95}Nb, ^{95}Zr, ^{90}Mo, ^{103}Ru, ^{105}Ru, ^{106}Ru, ^{131}I, ^{132}Te, ^{134}Cs, ^{136}Cs, ^{137}Cs, ^{133}Xe, ^{140}Ba, ^{140}La, ^{141}Ce, ^{144}Ce, ^{239}Np, ^{238}Pu, ^{239}Pu, ^{239}Pu, ^{241}Pu, ^{242}Cm

3. Product Interpretation

The standard set of ATDM forecast products for EER is defined in Appendix II-7 of the Manual on the GDPFS (WMO, 2010), and consists of seven charts and a concise statement on weather and atmospheric dispersion forecasts issued by RSMCs in the relevant Regional Association. Charts show forecasts of three-dimensional wind flow trajectory, time-integrated airborne concentrations, and depositions on the surface.

3.1 Trajectory (Figure 1)

Trajectories of three tracers released 500, 1500, and 3000 m above the surface at the source location are shown on a single chart. The tracers are let go at the start release time and move along the wind stream without disturbance from atmospheric diffusion, viscosity or turbulence. Forecasts are shown up to 72 hours after the forecast initial time. A time-series representation for the height of each tracer is also shown on the chart.

3.2 Airborne Concentrations (Figures 2 – 4)

The charts show the distribution of a 24-hour integration of concentration for radioactive materials. The values shown are averages between the surface and an altitude of 500 m. Distributions for the periods up to 24, 48, and 72 hours after the forecast initial time are presented on three individual charts in units of Bq s/m^3, which represents the number of radiological decays per cubic meter in the atmosphere for the specified 24-hour period.

3.3 Depositions (Figures 5 – 7)

The charts show the distribution of radioactive materials accumulated on the surface. Surface deposition is classified as either dry or wet. Scavenging by rain is generally taken into account as part of wet deposition. The charts indicate the total amount of deposition from both processes since the start release time. Distributions for the periods up to 24, 48, and 72 hours after the initial forecast time are presented on three individual charts in units of Bq/m^2, which represents the number of radiological decays per square meter at the surface per second.

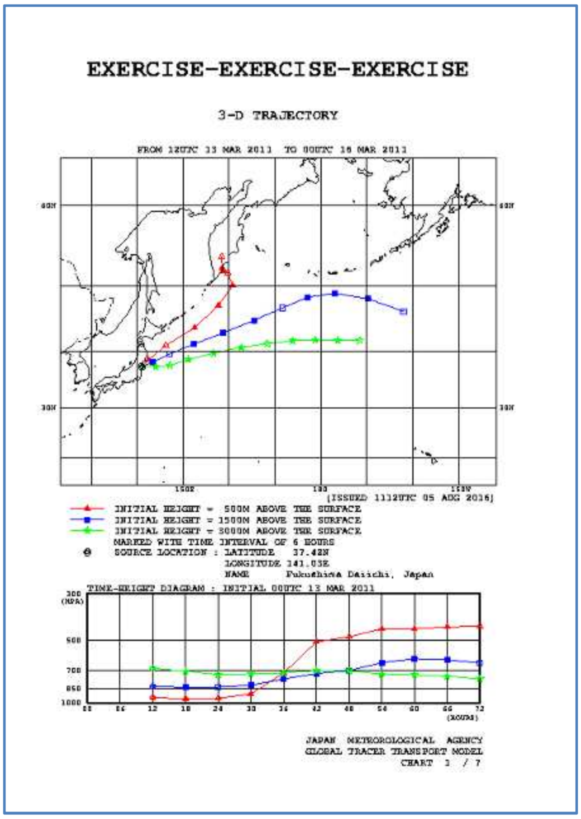

Figure 1. Trajectory chart

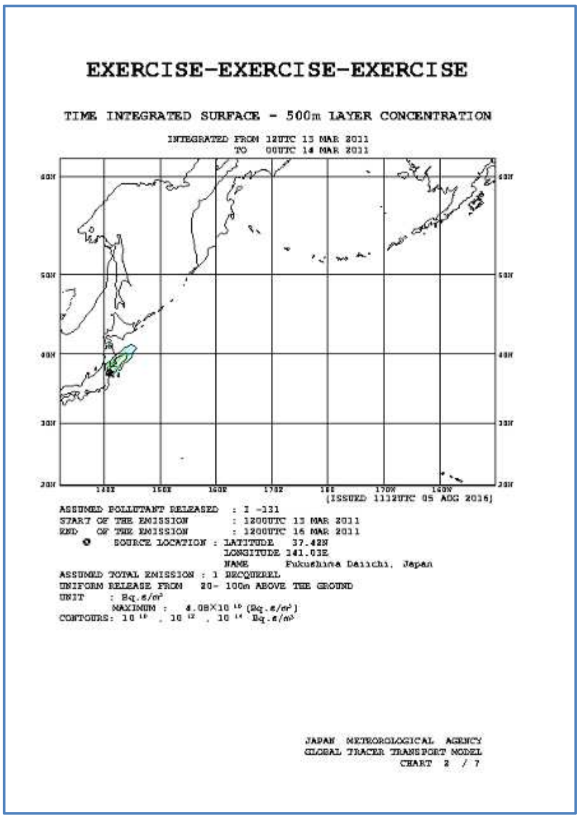

Figure 2. Airborne concentration

(up to 24 hours after the NWP initial time)

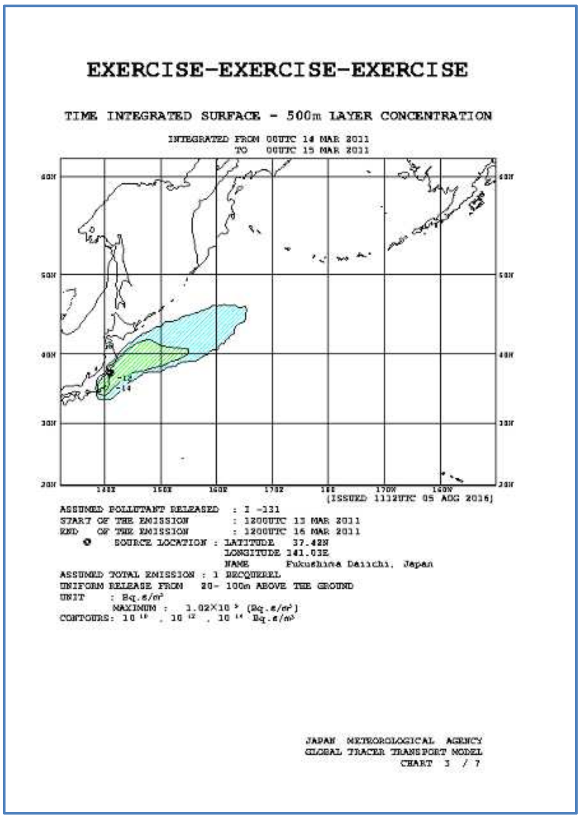

Figure 3. Airborne concentration

(up to 48 hours after the NWP initial time)

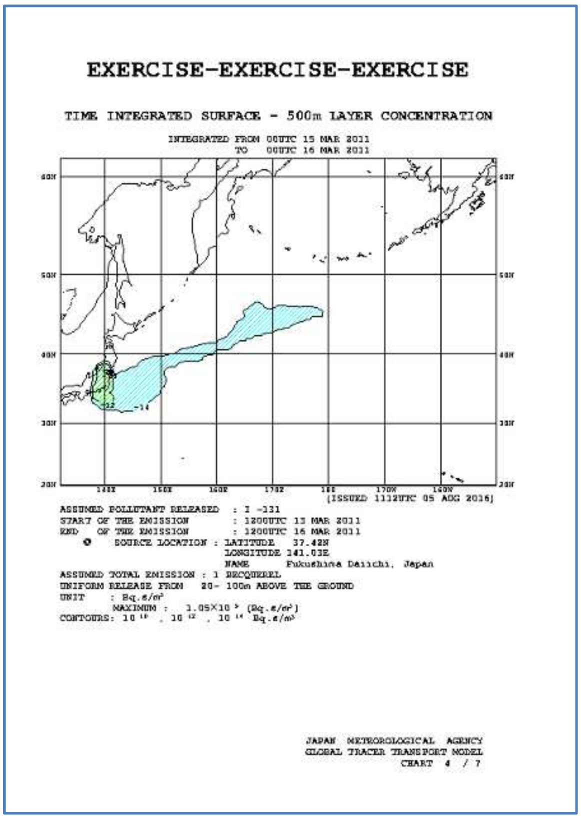

Figure 4. Airborne concentration

(up to 72 hours after the NWP initial time)

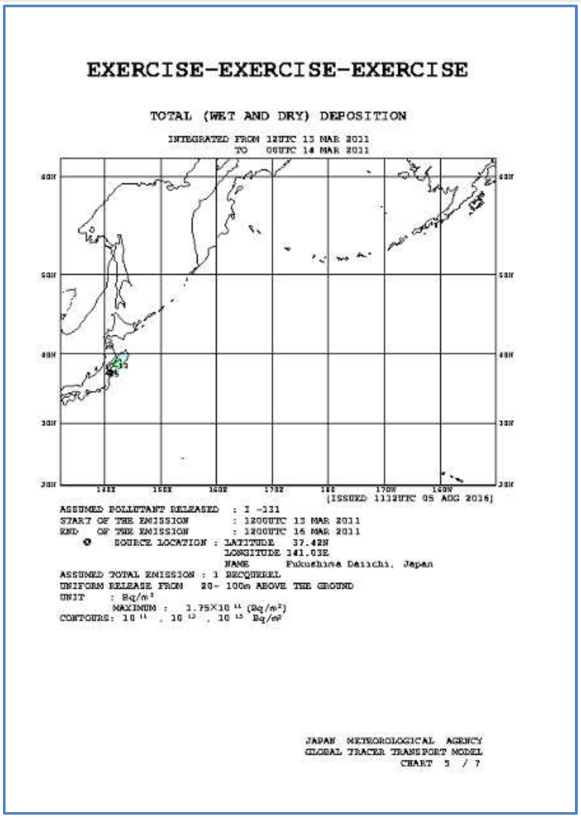

Figure 5. Total deposition

(at 24 hours after the NWP initial time)

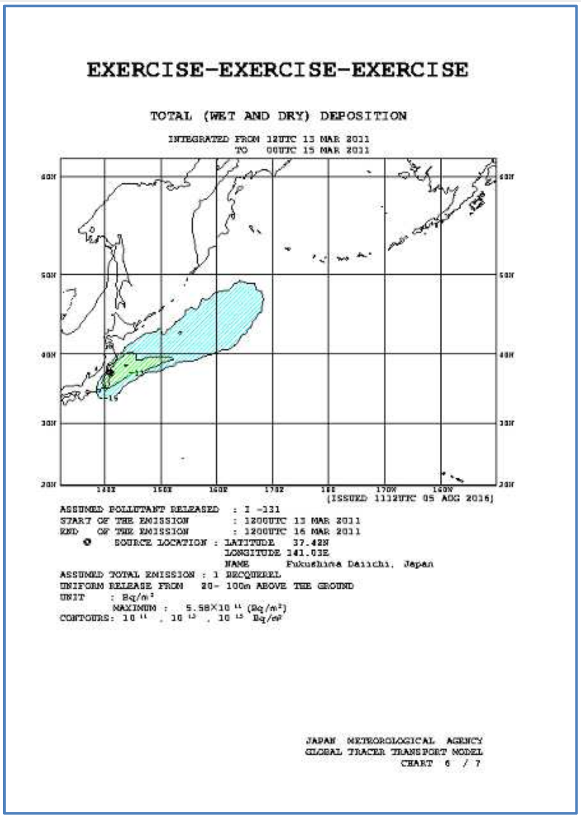

Figure 6. Total deposition

(at 48 hours after the NWP initial time)

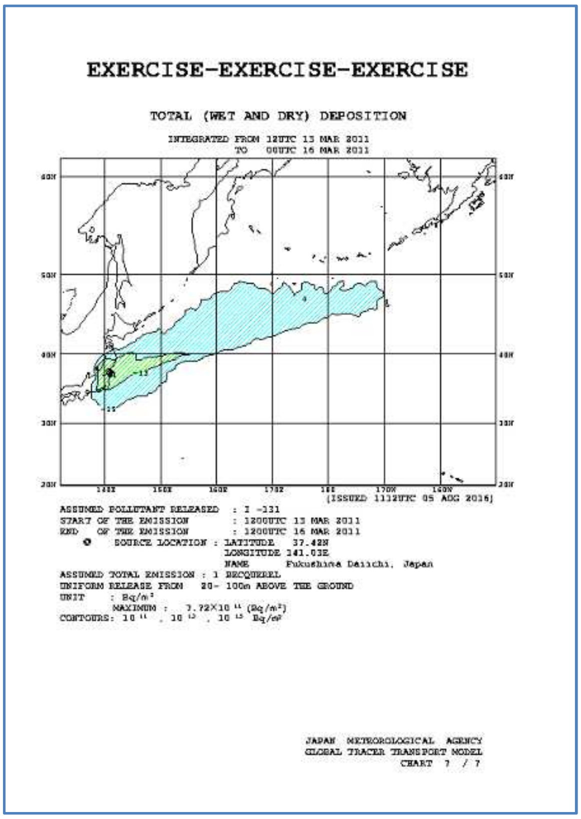

Figure 7. Total deposition

(at 72 hours after the NWP initial time)

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