1P11 Development of program to emulate reaction and diffusion of radioactive Gas/SPM

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Background:

We find new facts in 6 km from that accident point.

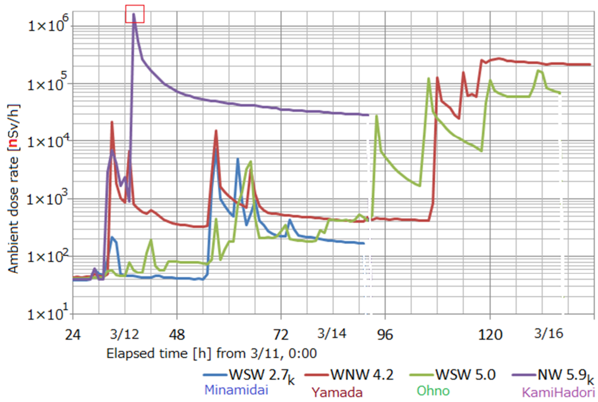

Figure1: Ambient dose rate [nSv/h] of direction WSW~NW in 6 km from a point {37.4214N, 141.0336E}.

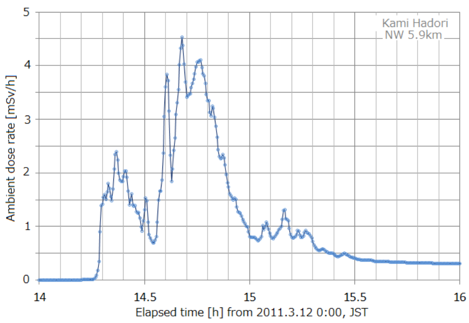

Figure 2: Enlargement of the part of a red square in figure 1.

Sampling rate is 20 s. Such concentration radioactive air passed over the point; however, after 1.3 h, the dose rate downs until 1/15 (4.53 to 0.305 mSv/h). The rate is not those of ^{132}Te or ^{131}I. Ventilation was completed at 14.5 h; irregular dose rate peaks are found from 4:00 am of the day. Something spouts from cracks of reactors. The 2 facts point out plumes of ^{133}Xe.

The Figure 3 does not show events of gas or suspended particulate matter (SPM); it would be solids that were fallen from the sky. Testimony in Futaba Town mayor Idogawa: *We heard a hydrogen explosion at 15:36, on March 12; at Futaba Public Welfare Hospital. After a few minutes, we saw that debris has been falling as snow.*

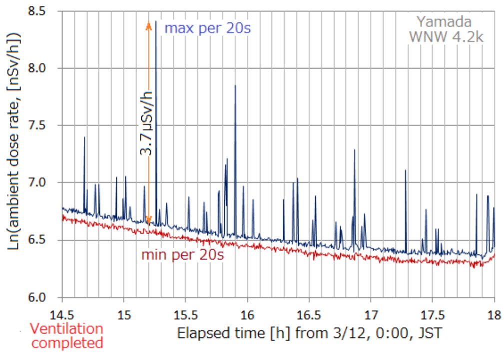

Figure 3: Fine structure of the maximum and minimal values of ambient dose rate that is found in per 20 s measurements; at Yamada MP, there is set at 4.2 km WNW direction.

To research environment around that point:

We discuss an approach to simulate time series reactions in the atmosphere. When we write a reaction, A+B=C; the compounds (A~C) are gas/SPM in the atmosphere. The density is ppm~ppb order. By the atmospheric flow, the compounds are moved as mass block that is a Gaussian of Full Width at Half Maximum, 736×927×20 m. The width is over half-reach distance of γ-ray, 70 m. We call the Gaussian “puff”.

The turbulence mixing is, in the Gaussian puff. A puff has many attribution; as an example, it includes plural radionuclides that are decayed by own half-life. If a puff collisions the ground, parts of radionuclide are deposited. The other parts are reflected by damping factor (0.70). When the deposition is over threshold, a puff is re-diffused from the ground. When two puffs of different compounds are attracted, they are reacted, and then a new puff is generated. By these generations, the number of puffs is increased. The motions are expressed by discrete time, and the interval is 10 min or 1 h. The deposition and reaction are advanced in a defined space. If a puff is out from the space, it is removed. If mass attribution is less than threshold (default 5%), the puff is removed. The simulation is an open system.

Expression of atmospheric unit:

We adopt a Gaussian having different parameters for the horizontal and vertical directions.

$G_A(\mathbf{r},z)=\mathbf{Q}_A\exp\{-\alpha_A(\mathbf{r}-\mathbf{r}_A)^2-\beta_A(z-z_A)^2\}$, (1)

The suffix A corresponds to compound A. The Q has density and the unit is [mol/volume] of compounds. In case of uncertain compounds chemically, it is replaced by [kg/volume]. In addition, it includes radio nuclei list, deposition ratio, and etc.; they are listed in Table 1. A vector “r” is for x- and y-coordinates, and “z” is for z-coordinate. A suffix “A” has sub-meanings of the center. The exp-function, whose argument is 3-dimensional distance, is a kind of local volume of the air. The α and β (positives) are diffusion parameters and they depend with elapsed time from the initialized time. In puff-model approaches, the dependency is calculated by many turbulence parameters. The model is effective in 10 km. On the other hand, in the Lagrangian model, assemble of L-particles represents the diffuse. The particle flows like as a volume unit. Gaussian puff has the character of the volume unit. We make the diffusion parameter a constant.

Table 1. Elements in **Qx/Qy***

1:3	Cartesian coordinates, {E,N,z}, [deg,deg,m]
4	Exponent, $\exp(-\alpha\mathbf{r}^2)$, correspond with {N}**
5	Mass of radioactive matter, default=1 : 10[kBq]
6	Deposition const., ratio, default=0.1/0.0*3
7:9	Ratio of nuclei, ^{131,133}I , ^{134,137}Cs, ^{132}Te

* On the 1st version; Qx is for SPM, Qy is for Gas. They are independent as movements, especially for turbulence.

** The exponents for {E,z} are const. in COMMON st.

*3 For re-diffusion.

Reactions:

In a time step, the chemical equilibrium of “A+B=C” is,

$K_{eq}=[C]/([A][B])$. (2)

For every times, mass attribution in **Q**;

$Q_A(t+\Delta t)=Q_A(t)-Q_C(t)$, $Q_B(t+\Delta t)=Q_B(t)-Q_C(t)$, (3)

$\mathbf{r}_A(t+\Delta t)=\mathbf{r}_A(t)+\{u,v\}_A\Delta t+\mathrm{Rand}()$, (4)

$Z_A(t+\Delta t)=Z_A(t)+\{w\}_A\Delta t+\mathrm{Rand}()$, (5)

Where, a vector {u,v,w} is wind speeds [km/time]. Rand() is normal distributed random numbers (σ=1, average=0), and Δt is time-intervals. In another reaction, A+B=C+D, we get,

$K_{eq}=([C][D])/([A][B])$, (6)

Since the distributions of C and D are same at the first step,

$G_C=G_D=(K_{eq}G_AG_B)^{0.5}$. (7)

Re-diffusion from the ground represented by mesh:

We discuss relations between the Gaussian and mesh of latitude and longitude. The coordinate of a mesh is $\{\mathbf{r}_m,z_m\}$, the intensity on the mesh point is $\mathbf{\Sigma}_A G_A(\mathbf{r}_m,z_m)$. We assume rediffusion is arisen from the mesh point. $\{\mathbf{\Sigma}_A G_A(\mathbf{r}_m,0)\}_m$,t is a deposition map for time-t.

Simulation of exhaust of once burst:

Initial conditions of an exhaust is altitude (100 m), rising velocity 1 m/s, 200 puffs (SPM:Gas = 1:1), once release. Radioactive mass of a puff is 10 kBq. Wind is direction of N (fixed), horizontal velocity (1m/s), a constant downward flow (10.8 m/h). The wind is set landing point to be the 30~35 km. Deposition constant is 0.1 (ratio of current mass) for SPM/Gas. Re-entrainment is happen when maximum deposit amount is over 500 Bq/m^2. Re-diffused puff doesn’t deposit.

Since many physical chemical phenomena are processed, the verification should be considered. Time series observation is required; we adopt measurements of the ambient dose rate. The difference between observations and calculations is feed backed to parameters; and *existence of a pole for parameter-scan gives significance*.

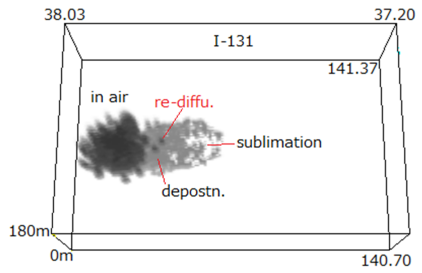

Figure 4: “Volume rendering image” of puffs and the deposit pattern on the ground. We can find a few re-diffusion and traces of the sublimation. The space is North latitude 37.20~38.03 deg, East longitude 140.70~141.37 deg, height 0~180 m. The puff-flows give Figure 5 at the distance of 35 and 45 km.

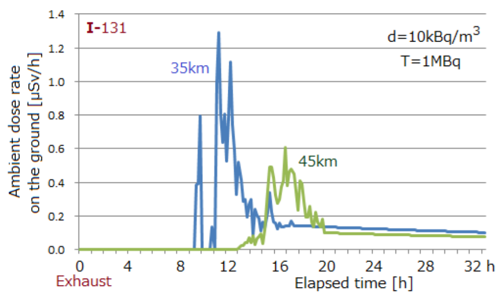

Figure 5: Ambient dose rates at 35/45 km points, which are calculated by ^{131}I only. It is calculated and confirmed that a slope shape after peaks is decreasing slowly.

Conclusion:

We are developing a simulator to calculate reactions and diffusion of Gas/SPM. Atmospheric behaviors of radioactive substances are emulated now roughly.