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MANUAL OF A SUITE OF COMPUTER CODES, EXPRESS

(EXact PREparedness Supporting System)

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Japan Atomic Energy Research Institute

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The emergency response supporting system EXPRESS (EXact PREparedness Supporting System) is constructed in JAERI for low cost engineering work stations under the UNIX operation. The purpose of this system is real-time predictions of affected areas due to radioactivities discharged into atmosphere from nuclear facilities. The computational models in EXPRESS are the mass-consistent wind field model EXPRESS-I and the particle dispersion model EXPRESS-II for atmospheric dispersions. In order to attain the quick response even when the codes are used in a small-scale computer, a high-speed iteration method MILUCR (Modified Incomplete Linear Unitary Conjugate Residual) is applied to EXPRESS-I and a kernel density method is to EXPRESS-II.

This manual describes the model configurations, code structures, related files, namelists and sample outputs of EXPRESS-I and -II.

Keywords: Emergency, Real-time, Environment, Nuclear Accident, Prediction, EXPRESS, Work Station, Concentration, Dose

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EXPRESS 大気拡散計算コード使用手引書

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茅野　政道

（1992年5月14日受理）

エンジニアリングワークステーションで利用可能な，原子炉事故時等の緊急時対策サポートシステムEXPRESS を開発した。このシステムの目的は，原子力施設からの放射能異常放出に対する実時間の汚染地区予測を目的としている。EXPRESS では，予測モデルとして質量保存風速場モデル（コード名 EXPRESS－Ⅰ）とランダムウォーク型大気拡散モデル（コード名 EXPRESS－II）を用いている。これらは，ワークステーションなどの小型の計算機においても迅速な評価が可能となるように，EXPRESS－Ⅰについては前処理付共役残差法による高速反復解法を採用し，EXPRESS－IIでは粒子数を減らしたことによる統計誤差を減らすために，カーネル濃度計算法を用いている。

本使用手引書は，両モデルの概要，プログラム構造，関連ファイル，ネームリスト，サンプル出力について記述している。

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The numerical evaluation methods of atmospheric dispersion and environmental doses in an emergency could be divided into two types, i.e., simplified calculations by small-scale computer and detailed calculations by vector processor.[1) However, some engineering work stations (EWS) which are recently developed make it possible to calculate environmental situations by using detailed models without much computation time. If we can perform real-time evaluations near the site by small-scale computer like EWS, the merits are large on the points of data communication, mobility, etc., comparing with a centralized system.

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2. Numerical Models in EXPRESS

In an emergency, calculations of wind fields, concentrations and doses are carried out sequentially. The models used in EXPRESS are a mass consistent model which is often used for predictions of wind fields in complex terrain and a particle dispersion model for concentration and dose calculations. The characteristics of mass consistent models are;

- Reasonable results are always expected by introducing the observed wind data in the model positively, although it is difficult to attain extremely high accuracy in complex terrain.
- The computational cost is small and the handling is easy, comparing with dynamic models.

EXPRESS-II employs a random walk model based on gradient-transfer theory. The merits of using marker particles for simulations are;

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- The computational cost is small and the handling is easy, comparing with dynamic models.

EXPRESS-II employs a random walk model based on gradient-transfer theory. The merits of using marker particles for simulations are;

- Numerical diffusion which sometimes appears in differential models can be eliminated.
- Much information, e.g., radioactivity, travel time, etc., can be added to particles.
- Numerical treatment is easy.

The γ-external doses are normally calculated by submersion model when the concentration distribution is not represented by analytic equation. However, models which employ a large number of particles can calculate γ-external dose by summing up the contributions from all the particles which are assumed to be point sources.

2.1 Wind Field Model EXPRESS-I

As shown in Fig. 2.1, this model consists of two procedures. The first step is an interpolation of observed wind data onto three-dimensional grid points, and the second step is an objective analysis to calculate mass-consistent wind fields by the minimal adjustment of interpolated wind data on the grids. The accuracy of wind fields predicted by this model greatly depends on the results of the first step. However, the second step is an essential procedure to avoid the unrealistic source/sink in the calculation of transport and diffusion processes of materials. Because ω-components of winds are not included in input data, ω-components which represent the airflow going over/around the mountain are also calculated by objective analysis in the second step.

The model generates three-dimensional airflows, but it does not provide turbulence information.

2.1.1 Interpolation Method (First Step)

Necessary input data for the interpolation are vertical wind profiles and surface wind data. In particular, wind profiles are important for vertical extrapolation in boundary layer. However, in practice, the available data are often limited to surface measurements owing to the difficulties of continuous routine measurements of wind profiles. It is sometimes unreasonable to use simple interpolation method when surface observatories are situated in various terrain height. It is because the stations at the peaks or ridges of mountains may measure the ambient winds which are relatively constant within local scale, while the stations at the base of mountain or valley measure the airflows affected by local topography.

Therefore, this model employed a new method for the weighted interpolation of surface wind data to three-dimensional mesh. This method is based on the meteorological measurements which were carried out in complex terrain for two months.[2),3)]

A weighted interpolation scheme is normally expressed as

$$(u,v)_{i,j} = \sum_{k=1}^{n}(u,v)_k W_k / \sum_{k=1}^{n} W_k, \tag{1}$$

where $(u,v)_{i,j}$ is grid value, $(u,v)_k$ is the observed value at the k-th station, n is the number of stations and W_k is the weighting factor of the k-th station. The weighting function introduced here is

$$W_k = W(r)W(h)W(h_b), \tag{2}$$

where $W(r)$ is a weighting function of the horizontal distance r between two points, $W(h)$ is a weighting function of the vertical distance h between two points, and $W(h_b)$ is a weighting function of the height of the terrain barrier h_b separating two points. Although the usual method uses the weighted interpolation by Eq.(1) only to a horizontal mesh at a reference-height, our method uses it onto a three-dimensional mesh. Thus, in order to obtain $(u,v)_k$ suitable for grid at an arbitrary height, the extrapolation of wind speed at the measured height up/down to a grid height is also discussed.

① Weighting function of horizontal distance $W(r)$

Several studies[4)] have already been devoted to the interpolation scheme of horizontal distance between two points. As there is no unique solution to interpolation, the Gaussian weighting scheme described by MacCracken and Sauter[5)] is used. The main aim of this scheme is to eliminate the complete dominance of a measuring station near a grid point, i.e.,

$$W(q) = \exp(-\alpha r^2), \tag{3}$$

where r is horizontal distance(km) between station and grid point and $\alpha = 0.1$ is proposed. Figure 2.2 shows the variation of $W(r)$ with horizontal distance.

② Weighting function of vertical distance $W(h)$

a) Weighting scheme when the station is higher than the objective grid:

As discussed in Ref.3), the weight of the station at the peak to the lower grid points decreases slightly with the vertical distance between two points, except for the grids in the vicinity of the base of the mountain. Thus, we introduce a weighting function,

$$W(h) = \exp\left[-\beta[h/(h_s-h_g)]^4\right] , \tag{4}$$

where h is the vertical distance(m) between the station and the grid point, h_s is the height(m) of the station above sea level and h_g is the terrain height(m) under the grid point. By using the 4th power, the weighting factor decreases little except for the grids near the ground. The variation of $W(h)$ by Eq.(4) is shown in Fig. 2.3. The unit of the abscissa is the vertical distance between two points normalized by the vertical distance between the station and the terrain under the grid point. Figure 2.3 shows that the weight changes according to the difference of elevation between the station and the terrain under the grid point as well as the vertical distance between two points. It indicates that the weight of the peak station to elevated grids above the ground is higher than that to grids near the ground, even if both of the h values are equal. For example, when β is equal to 2.3, the weight of the station at the peak (876 m) to the 500 m height grid above the base of the mountain (30 m), i.e., h is about 350 m, is 0.93, while the weight of the 25 m height grid on 500 m terrain, i.e., h is also 350 m, is 0.17.

b) Weighting scheme when the station is lower than the objective grid:

Surface winds at the base of mountain do not always represent the upper winds well. In particular, in a stable stratified condition, the stations at the base of the mountain will be located in airflow quite different from that in the upper area. Thus, the weighting factor is defined here by

$$W(h) = \exp(-\gamma h^2), \tag{5}$$

where h is the vertical distance between two points. The variation of $W(h)$ of Eq.(5) is shown in Fig. 2.4.

③ Weighting function of barrier $W(h_b)$

It is clear that the weights of stations in complex terrain decrease when terrain barriers separate two points. In order to consider the effect of a barrier, we introduced the following equation.

$$W(h_b) = \exp(-\eta h_b^2), \tag{6}$$

where h_b is the vertical distance of the top of the barrier from the station. Here, the barrier means the heighest terrain between the grid point and the station. The variation of $W(h_b)$ is the same as Fig. 2.4.

④ Wind speed for the interpolation

In order to use the observed winds for the interpolation, it is necessary to obtain $(u,v)_k$ in Eq.(1) by the extrapolation of the observed wind speeds U_{obs} up/down to the grid point, using the power law,[6] i.e.,

$$U(z) = U(z_0)(z/z_0)^p. \tag{7}$$

Surface wind data U_{obs} are generally used as data at the 10 m height above the ground, i.e., $U(z_0) = U_{obs}$ and $z_0 = 10$ m. However, wind data from Ref.2) showed that wind data from the peak station have characteristics similar to the ambient winds at the same height when multiplied by 1.5. Therefore, the wind speed for the interpolation is calculated by a two-step procedure. First, $U(z_0)$ is estimated by the following equation,

$$U(z_0) = U_{obs}\left[1+\xi[(h_s-h_g)/h_t]^q\right] \quad , \tag{8}$$

where h_s is the height of the station above sea level, h_t is the vertical distance between the peak and the base, h_g is the terrain height under the grid point and $\xi = 0.5$. Because the value of q cannot be defined from the analysis of experiments, we assume $q=p$ in Eq.(7) in this report, tentatively. This equation indicates that $U(z_0)$ varies from U_{obs} to 1.5 U_{obs} with the vertical distance between h_s and h_g. For example, $U(z_0)$ is $1.5U_{obs}$ when wind speed at the peak is used for the interpolation to the column on the base of mountain, because $h_s-h_g=h_g$. The detailed analysis of field data show the value of ξ in Eq.(8) varies according to the wind direction. However, because a lot of data must be examined to decide the value of ξ for each direction, we assume ξ to be a constant value in this study.

Second, $(u,v)_k$ is obtained by the extrapolation of $U(z_0)$ to the grid height by the power law, i.e., Eq.(7), where z_0 and z are the heights of station and grid above the base of mountain, respectively.

The important factors needed to determine the values of α, β, γ, η and ξ in Eqs.(3) to (6) and (8) are the heights of the surface-based inversion or mixed layer and the topographic features around the stations. When stations exist under the inversion or mixed layer, the weighting factor of these stations should be small to the grids above the layer, and vice versa. For example, if the surface-based inversion or mixed layer is shallow, γ must be large and β small. Where the observed winds are strongly affected by terrain features, the weighting factor will be significantly decreased by both vertical and horizontal distances; consequently, α and γ must be large.

In this model, the parameters for surface stations α, β, γ and η are equal to 0.1, 2.3, 5.75×10^{-5} and 1.15×10^{-4}, respectively, based on Ref.2). Furthermore, the parameters α = 0.1/ALOG10(0.1*STH) and $\gamma = 2.5 \times 10^{-5}$ are assumed for upper wind observatories. These two values are employed based on the following assumptions;

1) the representative areas of upper wind data are generally larger than those of surface station data,
2) upper wind data can represent the wind in the area higher than observed height, comparing with surface station.

In this model, the data from the stations whose observation heights STH above the ground are higher than 100 m are treated as upper wind data. Equation (8) is not applied to upper wind data.

In the program, three observatories whose weights are heavier to the objective grid are used for the interpolation.

2.1.2 Objective Analysis (Second Step)

The interpolated wind field (u_0,v_0,w_0) generated by the first step is adjusted so that it satisfies the mass conservation equation,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0. \qquad (9)$$

According to the variational analysis,$^{7),8)}$ mass consistent wind fields can be calculated by finding (u,v,w) which minimize the function,

$$E = \int_V \left[\alpha_1^2(u-u_0)^2+\alpha_1^2(v-v_0)^2+\alpha_2^2(w-w_0)^2+\lambda\left\{\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}\right\}\right]\mathrm{dv}\ . \qquad (10)$$

To obtain a minimum value of E, the mass consistent wind field (u,v,w) and the Lagrangian multiplier λ should satisfy Eq.(9) and following equations,

$$u = u_0 + \frac{1}{2\alpha_1^2}\frac{\partial\lambda}{\partial x}\ , \qquad (11)$$

$$v = v_0 + \frac{1}{2\alpha_1^2}\frac{\partial\lambda}{\partial y}\ , \qquad (12)$$

$$w = w_0 + \frac{1}{2\alpha_2^2}\frac{\partial\lambda}{\partial z}\ . \qquad (13)$$

Eqs.(9) and (11) to (13) can be reduced to Poisson's equation for λ,

$$\frac{\partial^2\lambda}{\partial x^2}+\frac{\partial^2\lambda}{\partial y^2}+\frac{\alpha_1^2}{\alpha_2^2}\frac{\partial^2\lambda}{\partial z^2} = -2\alpha_1^2\left(\frac{\partial u_0}{\partial x}+\frac{\partial v_0}{\partial y}+\frac{\partial w_0}{\partial z}\right), \qquad (14)$$

where, the boundary conditions are shown by

$$\lambda = 0,\ \text{or} \qquad (15)$$

$$n_x\delta u = 0,\ n_y\delta v = 0,\ n_z\delta w = 0.$$

The former condition is applied for free surfaces. The latter can be rewritten to $\partial\lambda/\partial n = 0$ by using λ and applied to the ground surface.

The value of α_1/α_2 in Eq.(14) is correspondent to the ratio of the adjustment of vertical component w to that of horizontal components u,v. It means that the adjustment for vertical component becomes large with the value of α_1/α_2 and, consequently, an airflow which goes over the mountain will be generated for the large value of α_1/α_2. On the contrary, when the α_1/α_2 value is small, a calculated airflow goes around the mountatin. Because the former situation appears in neutral and unstable conditions and the latter in stable condition, the values of α_1/α_2 are decided with atmospheric stability as shown in table below.

Value of the parameter α_1/α_2.

Stability	A	B	C	D	E	F	G
$\alpha_1\alpha_2^{-1}$	1.0	1.0	0.8	0.5	0.1	0.05	0.02

Figure 2.5 shows the difference of mass consistent flows with the values of α_1/α_2.

In the program, a staggered grid shown in Fig. 2.6 is employed to obtain finite difference expressions for Eqs.(11) to (14). All the wind velocity components are defined at the centers of six surfaces of a calculation cell, and λ is defined at the center of a cell. The finite differential expression of Eq.(14) forms a linear equation system for λ,

$$\frac{a_l\lambda_{i-1,j,k}+b_l\lambda_{i,j,k}+c_l\lambda_{i+1,j,k}}{(\Delta x)^2}+\frac{a_m\lambda_{i,j-1,k}+b_m\lambda_{i,j,k}+c_m\lambda_{i,j+1,k}}{(\Delta y)^2}+$$

$$\frac{\alpha_1^2}{\alpha_2^2}\cdot\frac{a_n\lambda_{i,j,k-1}+b_n\lambda_{i,j,k}+c_n\lambda_{i,j,k+1}}{(\Delta z)^2}$$

$$=2\alpha_1^2\left(\frac{u_{0,i+1,j,k}-u_{i,j,k}}{\Delta x}+\frac{v_{0,i,j+1,k}-v_{0,i,j,k}}{\Delta y}+\frac{w_{0,i,j,k+1}-w_{0,i,j,k}}{\Delta z}\right), \tag{16}$$

where, the values of $a_{l,m,n}$, $b_{l,m,n}$, $c_{l,m,n}$ are decided based on boundary condition of each cell, and values are shown in Table 2.1. By calculating $\lambda_{i,j,k}$ in Eq.(16) iteratively, mass-consistent wind field (u,v,w) can be obtained from Eqs.(17)-(19), which are also differential forms of Eqs. (11) to (13),

$$u_{ijk}=u_{0,ijk}+\frac{1}{2\alpha_1^2}\left(\frac{\lambda_{ijk}-\lambda_{i-1jk}}{\Delta x}\right), \tag{17}$$

$$v_{ijk}=v_{0,ijk}+\frac{1}{2\alpha_1^2}\left(\frac{\lambda_{ijk}-\lambda_{ij-1k}}{\Delta y}\right), \tag{18}$$

$$w_{ijk}=w_{0,ijk}+\frac{1}{2\alpha_2^2}\left(\frac{\lambda_{ijk}-\lambda_{ijk-1}}{\Delta z}\right). \tag{19}$$

To solve Eq.(16) iteratively, five types of Poisson's solvers are prepared.[9)]

- the odd-even SOR (successive over-relaxation) method,
- the ICCG (Incomplete Choresky Conjugate Gradient) method,
- the MICCG (Modified ICCG) method,
- the ILUCR (Incomplete Linear Unitary Conjugate Residual) method, and
- the MILUCR (Modified ILUCR) method.

Efficiency of each method was estimated in terms of the number of iteration and CPU time needed to converge iteration calculations. Results normalized by the values of O.E. SOR are summarized in Table 2.2. The ICCG method could not converge in 200 times of iterations. The number of iterations and the CPU time of the MICCG method were about a third and a half, respectively. The efficiency of the MILUCR method was the same as that of the MICCG method. Although the MICCG method and the MILUCR method have the best efficiency, both methods require considerable amount of pre-calculations to determine the optimum acceleration parameter. In particular, the number of iterations with the MICCG method highly depends on the parameter that should be determined case by case. The odd-even SOR method is developed for vector processors and has lower efficiency in scaler computers, comparing with other methods. From the results described above, it is concluded that;

- The ILUCR method has the best efficiency for the topography and atmospheric stability for which the optimum acceleration parameter has not been determined.
- For a fixed calculation domain for which the optimum acceleration parameter has been determined, the MILUCR method is the most efficient scheme.
- The ICCG method and the MICCG method are not in general suitable for the application.

In the EXPRESS-I, the MILUCR method with acceleration factor of 7×10^{-3} is employed as a default, although users can select other method as an option.

2.2 Concentration and Dose Model EXPRESS-II

2.2.1 Atmospheric Dispersion Model

In EXPRESS-II, the atmospheric dispersion of radioactivity is modelled by following the trajectories of a large number of marker particles which are discharged from the source and move downwind. The location of particles for sequential time steps with time interval of Δt is determined from

$$(x,y,z)_{new} = (x,y,z)_{old} + (u,v,w)\Delta t + \Delta(x,y,z). \tag{20}$$

In the equation, $(x,y,z)_{old}$ and $(x,y,z)_{new}$ are positions of particle at the start and the end of the time step. The second term of right hand represents the transport of particle by mean air flow, and the third term means the diffusion of particle by turbulence. As shown in Fig. 2.7, wind velocity (u,v,w) at the particle position can be calculated by the $1/r^2$ weighted interpolation of wind vectors on the eight grid points which surround the particle. Equation is

$$(u,v,w) = \sum_{j=1}^{8} ((u,v,w)_j/r_j^2)/(1/r_j^2) , \tag{21}$$

where $(u,v,w)_j$ is wind vectors at grid j and r_j is the distance between particle and grid j. The wind field (u,v,w) on the 3-D grid is provided from EXPRESS-I.

The diffusion term $\Delta(x,y,z)$ is calculated based on the gradient-transfer theory.[10),11)] According to the theory, the diffusion term can be shown by tensor expression $(i=x,y,z)$,

$$\frac{\partial}{\partial x_i}\left(K_i\frac{\partial C}{\partial x_i}\right) = \frac{\partial K_i}{\partial x_i}\frac{\partial C}{\partial x_i} + K_i\frac{\partial^2 C}{\partial x_i^2} . \tag{22}$$

The first term in right hand represents the transport of particle by quasi wind speed K_i', where $K_i' = \partial K_i/\partial x_i$, and the second term represents the random displacement whose standard deviation is defined by $\sqrt{2K_i\Delta t}$ and the mean of 0. Thus, the total diffusion step should be expressed by the probability density function whose standard deviation is $\sqrt{2K_i\Delta t}$ and whose mean is equal to $K_i'\Delta t$. Consequently, the expansion of z-direction diffusion is shown by

$$\begin{aligned}\Delta z &= K_z'\Delta t \pm\sqrt{2(K_{0z} + \tfrac{1}{2}K_z'(K_z'\Delta t))\Delta t} \\ &= K_z'\Delta t \pm\sqrt{2K_{0z}\Delta t + (\Delta t K_z')^2},\end{aligned} \tag{23}$$

where K_{0z} is a diffusion coefficient at the old particle position and K_z' is a gradient of diffusion coefficient which is treated by differential form in the code.

Because the model assumes the spatial constant of horizontal diffusion coefficient (i.e., $K'_{i=x,y} = 0$), the horizontal fluctuation step is calculated by a simple distribution function which has a standard deviation,[12)]

$$\sigma_i = \sqrt{2K_{0,i}\Delta t},\ (i=x,y). \tag{24}$$

EXPRESS-II employs a uniform distribution function and, for example, Δx is shown by

$$\Delta x = [R]^{-\beta}_{-\beta}. \tag{25}$$

This equation shows the unform random number from $-\beta$ to β. In order to make the standard deviation of Δx equal to $\sqrt{2K_x\Delta t}$, the value of β is defined by $\sqrt{6K_x\Delta t}$. By using the random number $R(0)$ between 0 and 1, Δx can be rewritten by

$$\Delta x = \sqrt{24K_x\Delta t}(0.5 - R(0)). \tag{26}$$

The diffusion coefficient $K_i(i=x,y)$ is defined by

$$K_i = \frac{1}{2}\frac{d\sigma_i^2}{dt} = \frac{1}{2}\frac{dr}{dt}\frac{d\sigma_i^2}{dr} = u\sigma_i\frac{d\sigma_i}{dr}\ ,^{13)} \tag{27}$$

where σ_i is the standard deviation of the plume distribution. From a practical point of view, $\sigma_{x,y}$ at the particle position is derived from Pasquill-Gifford chart[14)] according to the atmospheric stability category determined from routine measurements in the nuclear sites.

Diffusion coefficient K_z is calculated by

$$K_z = u * f(st), \tag{28}$$

where u is the wind speed at a height of $z(m)$ and $f(st)$ is a factor which depends on atmospheric stability st. According to Eq.(27), $f(st)$ is correspondent to $(d\sigma_z/dr)\sigma_z$, whose variation with distance is shown in Fig. 2.8. Figure 2.8 shows $f(st)$ saturates at about 2 km downwind in the neutral and stable conditions. In the model, the saturated values in Fig. 2.8 are employed as $f(st)$. The values of $f(st)$ for unstable conditions are artificially decided so that unrealistically large diffusion can be eliminated. In the model, three thermally stratified layers can be considered.$^{15)}$ For example, a capping inversion can be treated as shown in Fig. 2.9 by the input of inversion height and stabilities under/in the inversion layer.

The value K'_z in Eq.(23) is estimated by the method shown in Fig. 2.10.

2.2.2 Estimation of Concentration and Doses

EXPRESS-II outputs air concentration at the ground level, wet and dry depositions, air dose rate, γ-external dose, thyroid dose and other internal doses due to inhalation.

(1) Air Concentration

Although it is the simplest way for dispersion models which employ marker particles to reduce the number of particles for the reduction of the memory and the CPU time, it directly increases the statistical error. Thus, a Kernel Density Estimation (KDE) Method,$^{16),17)}$ instead of counting the number of particles in cell, is applied to prevent the statistical error. The KDE method is one of methods to estimate concentrations from the distribution of particles. In this method, a numerical function KDE (Kernel Density Estimator) which decides the distribution of each particle's mass is employed. In EXPRESS-II, the distribution of each particle's mass is assumed to be the Gaussian.$^{18)}$ Thus, the concentration which is allotted to the evaluation point (x,y,z) from the unit-mass particle at the point (X,Y,Z) is expressed by

$$\chi(x,y,z) = (1/(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z) exp\left(-\frac{(x-X)^2}{2\sigma_x^2}\right) \tag{29}$$
$$exp\left(-\frac{(y-Y)^2}{2\sigma_y^2}\right)\left\{exp\left(-\frac{(z-Z)^2}{2\sigma_z^2}\right) + exp\left(-\frac{(z+Z-2z_g)^2}{2\sigma_z^2}\right)\right\},$$

where $\sigma_x(=\sigma_y)$ and σ_z are standard deviations of KDE, z_g is terrain height below the evaluation point. The concentration at the point (x,y,z) is calculated by summing up the contributions from all the particles. In the model, by the increase of $\sigma_{x,y}$ with the travel distance, one particle can cover large area in the region far from the release point and, consequently, the statistical error will be decreased. Although the value of

σ_y increases by $\sigma_y^2(t + \Delta t) = \sigma_y^2(t) + 2K\Delta t$, σ_z is assumed to be the constant value of 25 m. It is because the effect of wind shear will be obscure by the increase of σ_z. In the model, air concentration values at the ground level ($z = z_g$) are only calculated for the reduction of the memory and the CPU time. Thus, the particles whose heights above the ground are higher than 75 m ($= 3\sigma_z$) are eliminated from the calculation of air concentration at the ground level.

Because it is time-consuming work to calculate Eq.(29) for all the particles, the values of χ are calculated beforehand with several parameters and stored as table values in an input file (KDE concentration file). In the EXPRESS-II calculation, the table values whose parameters are closest to the real particle's situations are picked up as approximated values, instead of real calculations of Eq.(29). Thus, the concentration is calculated by $\chi = \sum_{i=1}^{N} Q_i \chi_i(h, z_d, \beta)$, where N: the number of particles, Q_i: radioactivity of particle i, $\chi_i(h, z_d, \beta)$: table value of Eq.(29) applied to particle i and $h, z_d (= z - z_g)$, β: table parameters.

Additional merits of the KDE method are, firstly, it is possible to calculate concentrations at arbitrary points and, secondly, it is easy to make spatial resolution finer near the release point by the decrease of the standard deviation of KDE.

(2) Dry and Wet Depositions

The dry and wet depositions are considered in the model. The wet deposition $G_w (Bq/m^2)$ allotted to the point(x,y) from the particle at the point(X,Y,Z) during Δt is expressed by

$$\begin{aligned} G_w(x,y) = & \left\{ (Q_i(1 - exp(-\Lambda\Delta t)) \right. \\ & \underline{\left. /(2\pi\sigma_x\sigma_y) \right\} exp\left(-\frac{(x - X)^2}{2\sigma_x^2}\right) exp\left(-\frac{(y - Y)^2}{2\sigma_y^2}\right)} . \end{aligned} \qquad (30)$$

The dry deposition can be expressed by

$$G_d(x,y) = v_g Q_i X_i(h, z, \beta)\Delta t, \qquad (31)$$

where, Q_i: radioactivity of particle i (B_q),
Λ : washout coefficient (s^{-1}),[19)]
v_g: deposition velocity (m/s).[20)]

For the calculation of wet deposition, the KDE method is employed and the underlined term of Eq.(30) is pre-calculated and stored in the KDE concentration file. Radioactivity deposited on the ground is substructed from the radioactivity of particle. The dry deposited is considered against only particles whose heights above the ground are within 75 m (= $3\sigma_z$).

(3) Air Dose Rate and External Dose Due to γ-Ray

The KDE method is also applied to the air dose rate calculation due to a radioactive cloud. The air dose rate $D_i(E_\gamma, r, z_d/r)$ which is allotted to the evaluation point (x,y,z) from the unit-mass particle at the point (X,Y,Z) are pre-calculated and stored in the input file (KDE dose file) with several parameters as well as χ_i. The equation for D_i is

$$D_i(E_\gamma, r, z_d/r) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{0}^{\infty} \frac{K_1 \mu_{en} E_\gamma exp(-\mu r)}{4\pi r^2} B(E,r)\chi(x,y,z)dzdydx. \tag{32}$$

Where, $\chi(x,y,z)$ is by Eq.(29) and the meanings of other symbols are the same as normally used. The meanings of the table parameters $E_\gamma, r, z_d/r$ are γ-energy, distance between two points and sine of angle, respectively. Figure 2.11 shows the parameters for χ_i and D_i.

The γ-external dose $D_{\gamma,g}(x,y)$ due to ground-shine is calculated by the following equation,

$$D_{\gamma,g}(x,y) = f_g G(x,y), \tag{33}$$

where, $G(x,y)$: deposition (Bq/m^2),
f_g : dose conversion factor $((mSv/h)/(Bq/m^2))$.[21]

(4) Thyroid Dose Due to Inhalation

Thyroid doses $D_{thy}(mSv/h)$ due to inhalation of radioiodine are calculated against three age groups (Adult, Children, Infant) by the following ICRP equation,[22]

$$D_{thy} = \frac{K_2}{0.693}\frac{\varepsilon T_{eff}}{m} * f * Res * \chi(x,y), \tag{34}$$

where, ε : effective energy against organ (MeV/Bq),
m : mass of thyroid (g),
T_{eff} : effective half life (h),
f : transport factor to the organ,
Res : respiration (m^3/h),
$\chi(x,y)$: air concentration of iodine (Bq/m^3),
K_2 : dose conversion factor $(g\ mSv/(MeV\ h))$.

(5) Other Internal Dose due to Inhalation

Internal doses $D_{inh}(mSv/h)$ due to inhalation are calculated against three age groups by the following equation,

$$D_{inh} = \chi Res D_f, \tag{35}$$

where, Res: respiration rate (m^3/h),

χ : air concentration of nuclide (Bq/m^3),

D_f : Dose conversion factor for effective dose equivalent or organ dose (mSv/Bq).

In the outputs mentioned above, air concentration, deposition and air dose rate due to cloud-shine are calculated in every time step and accumulated during the output dump interval. Here, the dump interval means the output interval of calculated results. For example, if the concentration distribution every one hour is needed, the dump interval is one hour. Because instantaneous air concentration and air dose rate are calculated by dividing accumulated ones by dump interval, physical meanings are averaged values during the dump interval. Air dose rate due to ground-shine, γ-external dose, thyroid and other internal doses are calculated at the end of each dump interval base on deposition, air dose rate and air concentration which are calculated at every time step.

2.2.3 Radioactive decay

Physical quantities which vary with radioactive decay are mass of radioactivity and effective and averaged energies of γ-rays of the nuclides. EXPRESS-II considers the temporal variations of them based on the following assumptions.

- All the decay corrections are carried out from the shutdown time. Thus, the release rates are converted to the values at the shutdown.
- Although physical quantities above change continuously during the dump interval (typically 1 hour), the model assumes them constant in the interval and uses averaged values over the dump interval for the dose calculation and the decay correction.

On the basis of these assumptions, EXPRESS-II includes the following calculations.

- Conversion of the release rates at arbitrary time to those at the shutdown time. When the release rates of mixed noble gases or iodines at arbitrary time are input, these are converted by

$$Q_0 = Q_t / \sum_{i=1}^{N} f_i exp(-\lambda_i t), \tag{36}$$

where, f_i: composition ratio of nuclide i of noble gases or iodines in fuel rod,[23)]

λ_i: decay constant (-s),

t : time interval from the shutdown to arbitrary time (s),

Q_t: release rates of noble gases or iodines at the arbitrary time (Bq/h),

Q_0: release rates of noble gases and iodines converted at the shutdown time (Bq/h),

N : the number of nuclides included in noble gases or iodines.

- Calculation of decay rate from the shutdown to the objective time, effective and averaged γ-ray energies of noble gases and iodines at the objective time. Decay rate is expressed by

$$QREL = \sum_{i=1}^{N} f_i exp(-\lambda_i t), \tag{37}$$

effective energy of mixed gases,

$$E_{eff} = \sum_{i=1}^{N} E_{i,eff} R_i, \tag{38}$$

averaged energy of mixed gases,

$$E_{ave} = E_{eff} / \sum_{i=1}^{N} R_i \sum_{i=1}^{N} p_{i,j}, \tag{39}$$

where, R_i is composition ratio of nuclide i at the objective time, which is expressed by

$$R_i = f_i exp(-\lambda_i t) / \sum_{i=1}^{N} exp(-\lambda_i t). \tag{40}$$

$E_{i,eff}$ is effective energy of nuclide i, $\sum_{i=1}^{N} p_{i,j}$($p_{i,j}$: emission rate of j-th γ-ray per decay of nuclide i and M: the number of γ-rays of nuclide i) is expressed by $E_{i,eff}/E_{i,ave}$. Averaged energy E_{ave} is used as a parameter to extract the D_i value from the KDE dose table and the real dose is calculated by multiplying the value of E_{eff}/E_{ave} to the table value extracted. In Eqs.(36) to (40), the values of f_i and λ_i,$E_{i,eff}$,$E_{i,ave}$ are input data from the nuclide composition file and the physical constant file, respectively.

- Instead of the correction of decay against the radioactivities allotted to particles, the correction is carried out against the calculated air concentration, deposition and air dose rate. It means that decay is considered not at each time step but at the dump of output, by multiplying QREL by air concentration, deposition and air dose rate.

2.2.4 Coordinates

The Cartesian coordinate system is employed for wind field, concentration and dose models. Figure 2.12 shows the horizontal coordinates. When the numbers of terrain mesh are I and J in x- and y-directions, terrain data are defined as averaged values of each cell and the array of terrain data is (I-1,J-1). Wind field mesh has a lower-left corner at the 2-mesh inside of lower-left point of terrain mesh and, consequently, the array of data is (I-4,J-4). Air concentrations and doses are defined at the center of the cells and the array of both data is (I-5,J-5).

The vertical coordinate system is shown in Fig. 2.13. The origin of coordinate is the bottom of computational region. Terrain features are converted to the block topography by using the mesh height which is nearest to the real terrain height. Because the wind fields are defined at the grid points, the array of wind data is (I-4,J-4,N). In EXPRESS-II, the N+1-th mesh is prepared for the particles which go over the N-th mesh, where the width from N to N+1 is equal to that from 1 to N. At the N+1-th point, the same horizontal winds as the N-th grid are applied and ω-component is set to 0.

In the computational code, I, J and N are set to 51, 51 and 21, respectively. Thus, terrain data are 50 × 50, wind field data are 47 × 47 × 21 and concentration and dose data are 46 × 46.

When the models employ 'block' topography, the dent of block like a well shown in Fig. 2.14 sometimes appears in highly complex terrain. It is clear base on experiences of many types of simulations that such dents generate strange high/low concentration spots. Thus, EXPRESS-I makes such dents smooth (see Fig. 2.14) in subroutine TOPOO and EXPRESS-II in subroutine GRAND. Although it is easy to eliminate the smoothing process in the programs, it should be done in both programs in the same time.

Table 2.1 Coefficients of finite difference approximation of second derivative.
$[a_l\lambda_{i-1}+b_l\lambda_i+c_l\lambda_{i+1})/(\Delta x)^2]_{j,k}$

Boundary condition at $i-½$	a_l	b_l	c_l	Boundary condition at $i+½$
No boundary	1	−2	1	No boundary
$\partial\lambda/\partial x=0$	0	−1	1	No boundary
No boundary	1	−1	0	$\partial\lambda/\partial x=0$
$\partial\lambda/\partial x=0$	0	0	0	$\partial\lambda/\partial x=0$
$\lambda=0$	0	−4	4/3	No boundary
No boundary	4/3	−4	0	$\lambda=0$
$\lambda=0$	0	−8/3	0	$\partial\lambda/\partial x=0$
$\partial\lambda/\partial x=0$	0	−8/3	0	$\lambda=0$

Table 2.2 Efficiency of solution methods of Poisson's equation.

	E.O.SOR	ICCG	MICCG	ILUCR	MILUCR
Iterations	1.00	——	0.29	0.50	0.28
CPU time	1.00	——	0.42	0.82	0.45
Pre-calculations	Optional	None	Needed	None	Needed

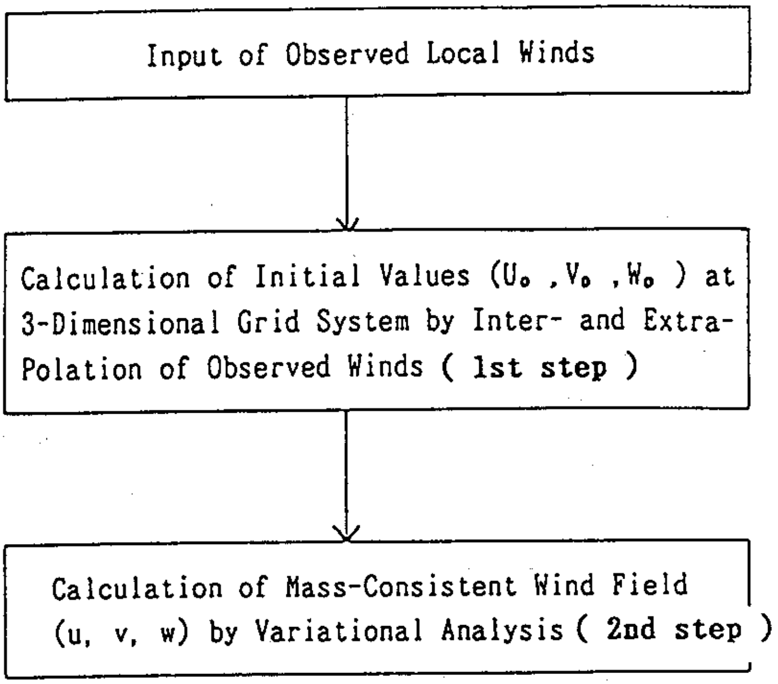


Fig. 2.1 Overall concept of method to calculate three-dimensional mass-consistent wind field.

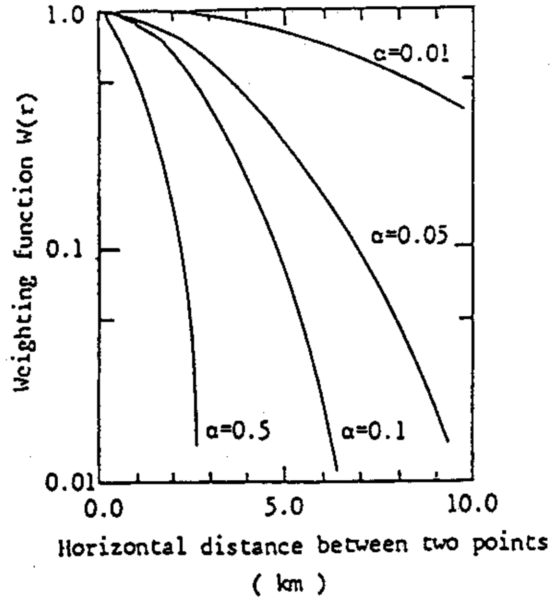


Fig. 2.2 Variation of horizontal weighting factor W(r) with horizontal distance between two points.

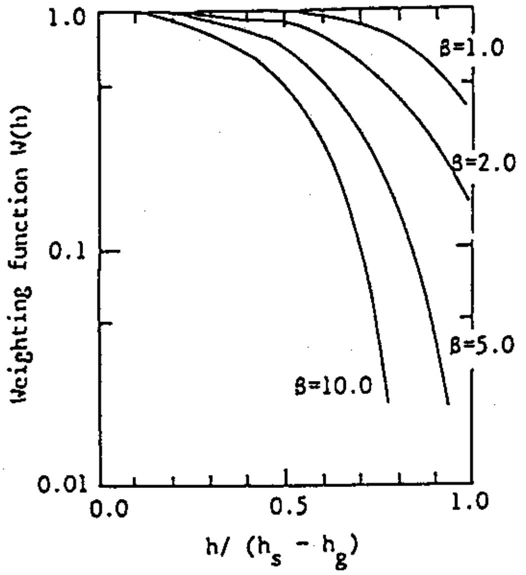


Fig. 2.3 Variation of vertical weighting factor W(h) with vertical distance between two points; When station is higher than objective grids.

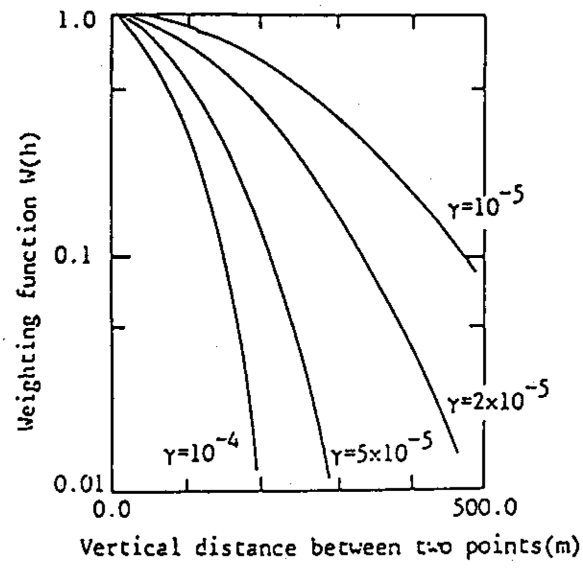


Fig. 2.4 Variation of vertical weighting factor W(h) with vertical distance between two points; When station is lower than objective grid.

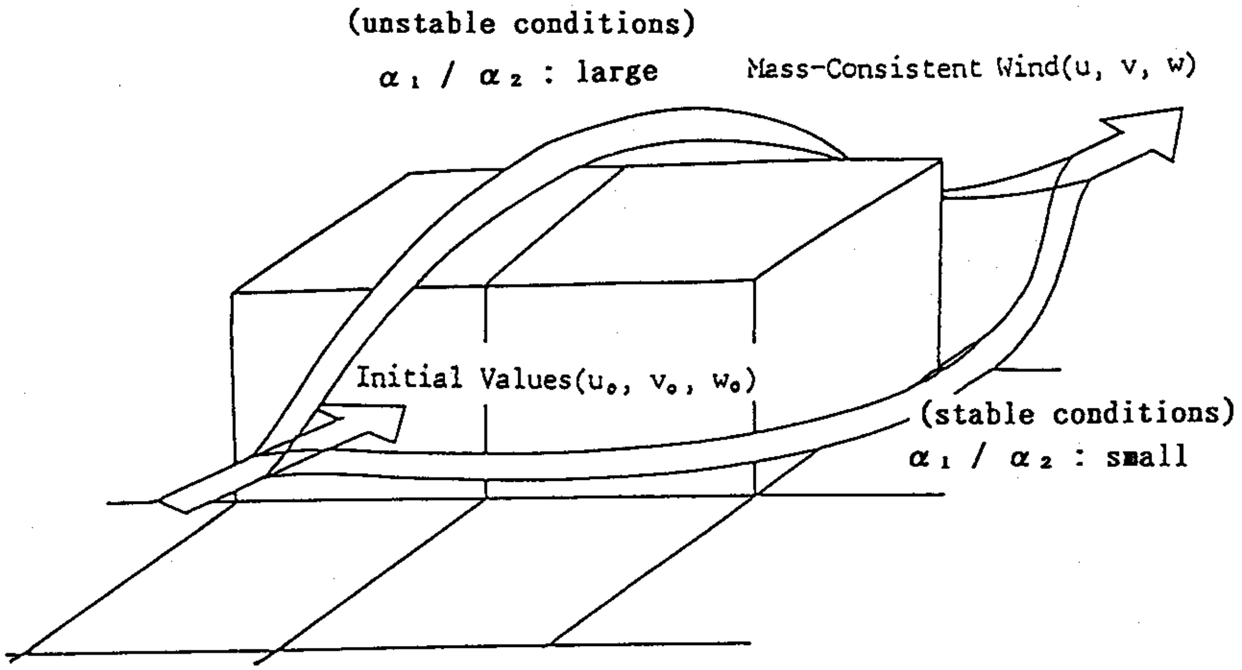


Fig. 2.5 Conceptual representation of airflow going over or around mountain generated by variational analysis.

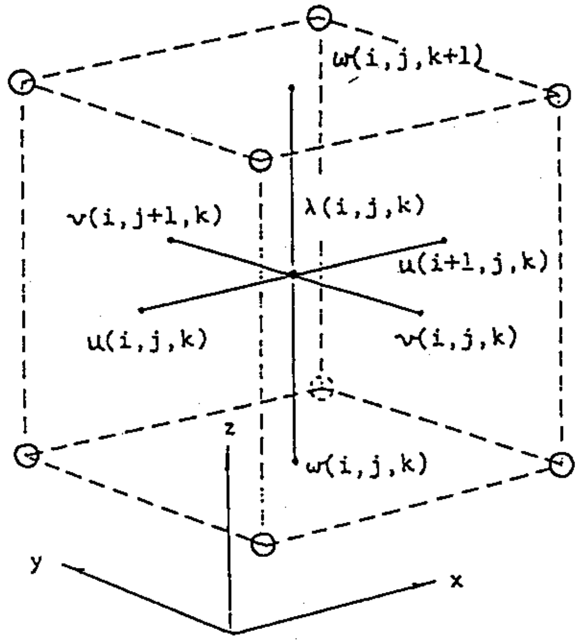


Fig. 2.6 An unit cell of the three-dimensional staggered network.

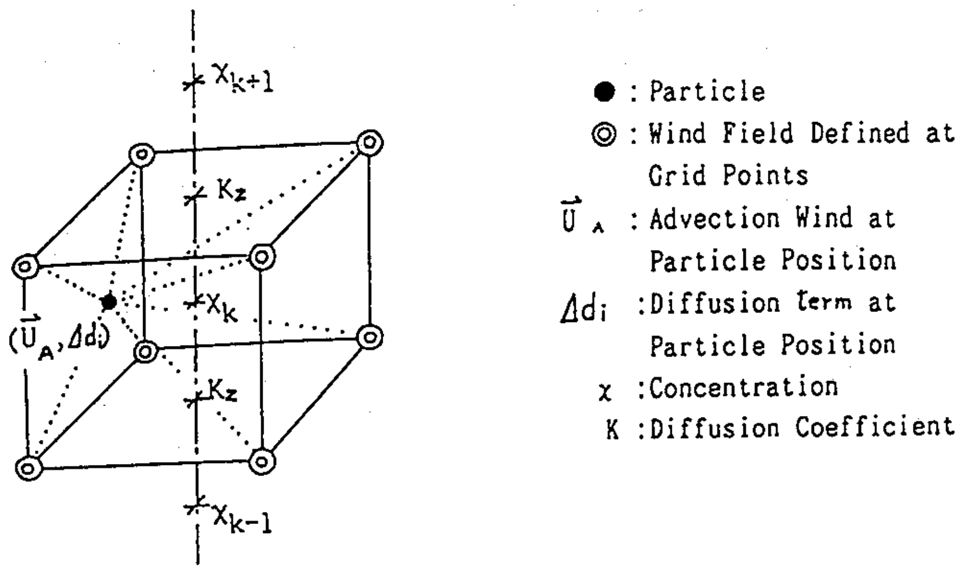


Fig. 2.7 Diagram of physical quantities related to advection and diffusion velocities.

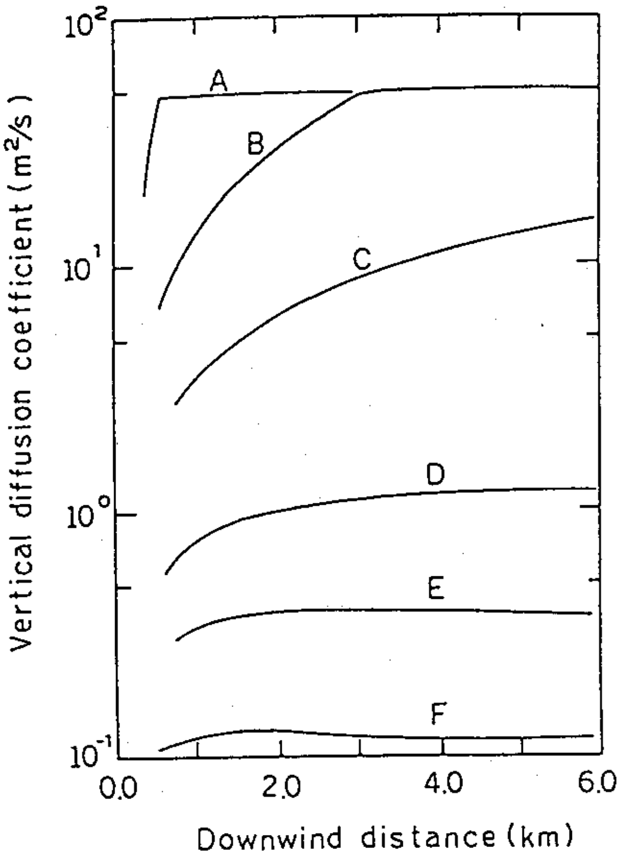


Fig. 2.8 Vertical diffusion coefficient calculated by Eq.(27). (u = 1 m/s)

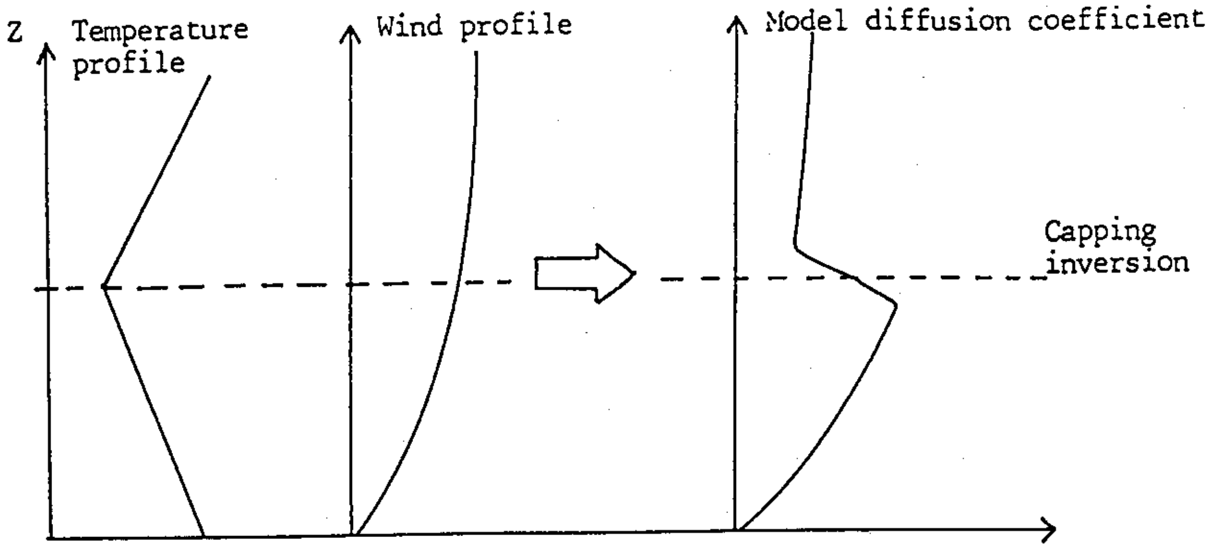
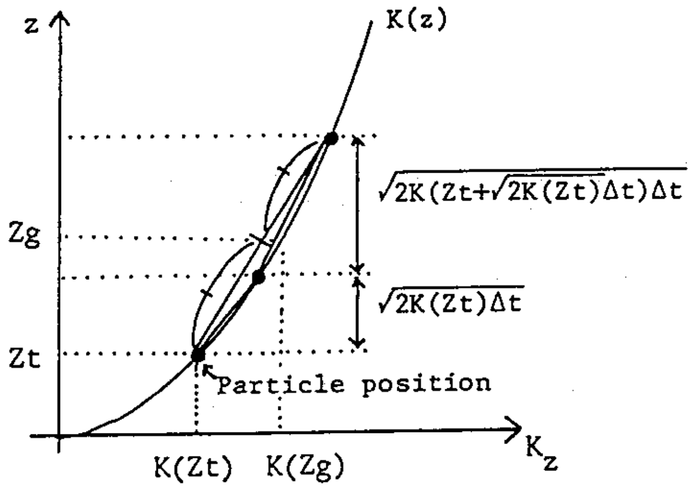


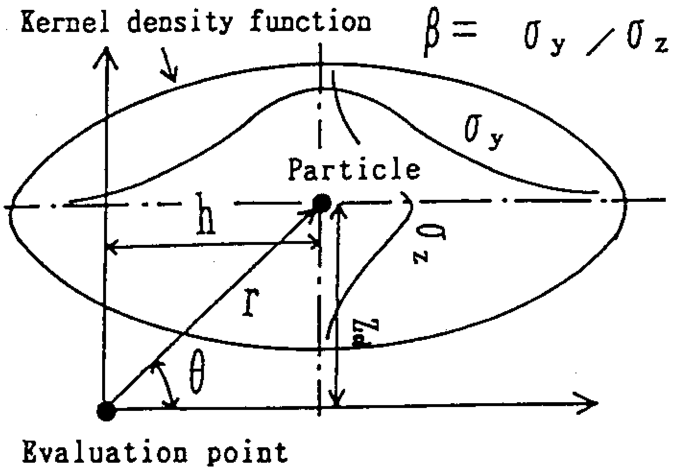
Fig. 2.9 Example of model Kz in the case of capping inversion.



$$Zg = \frac{1}{2}\left(\sqrt{2K(Zt)\Delta t} + \sqrt{2K(Zt+\sqrt{2K(Zt)}\Delta t)\Delta t}\right) + Zt$$

Gradient of K_z: $K' = \dfrac{K(Zg) - K(Zt)}{Zg - Zt}$

Fig. 2.10 Calculation method for vertical diffusion coefficient gradient.



Concentration parameter

- h = 0, 25, 50, 100, ..., 1000 m
- z_d = 0, 7.5, 15, 22.5, ..., 75 m
- β = 1, 3, 5, ..., 21

Dose parameter

- $E\gamma$ = 0.02 ~ 2.0 MeV (divided into 17)
- $r = 10^n$ (n=1, 1.25, 1.5, ..., 3.0)
- $\sin\theta$ = 0.1, 0.3, 0.5, ..., 0.9

Fig. 2.11 Parameters used for KDE concentration and dose data table.

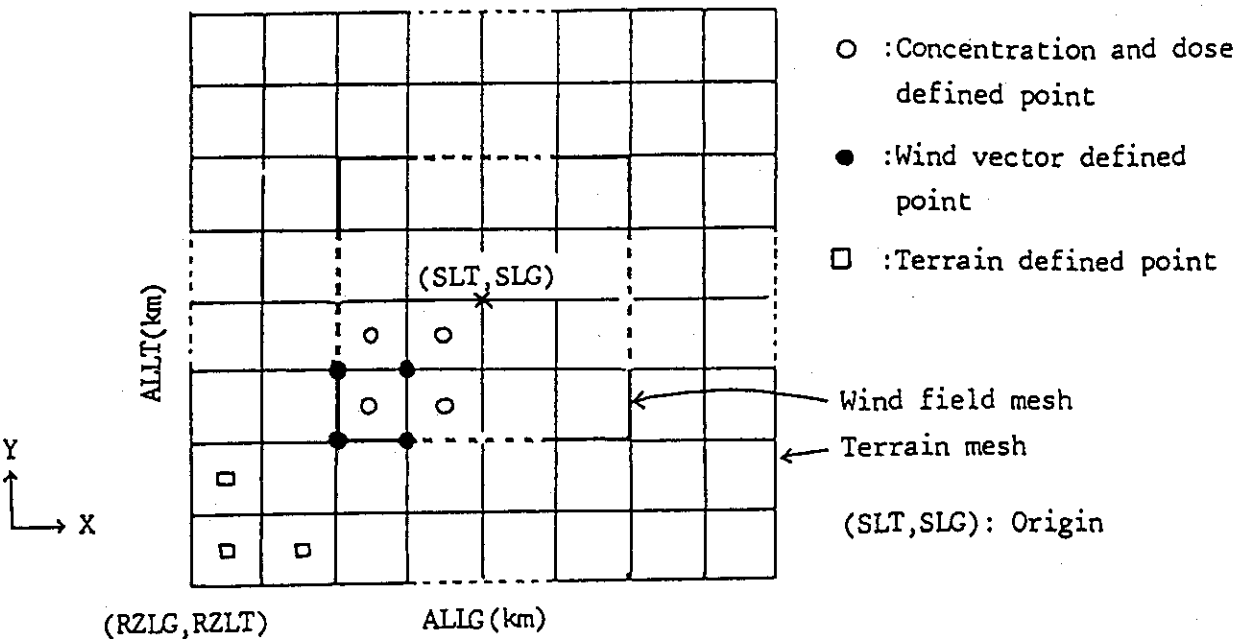


Fig. 2.12 X - Y coordinate in the model.

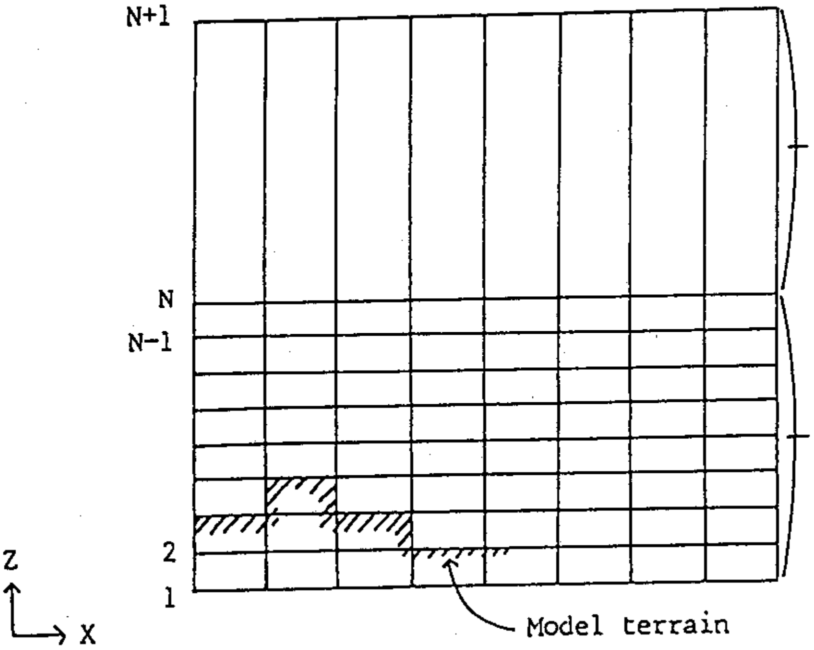


Fig. 2.13 X - Z coordinate in the model.

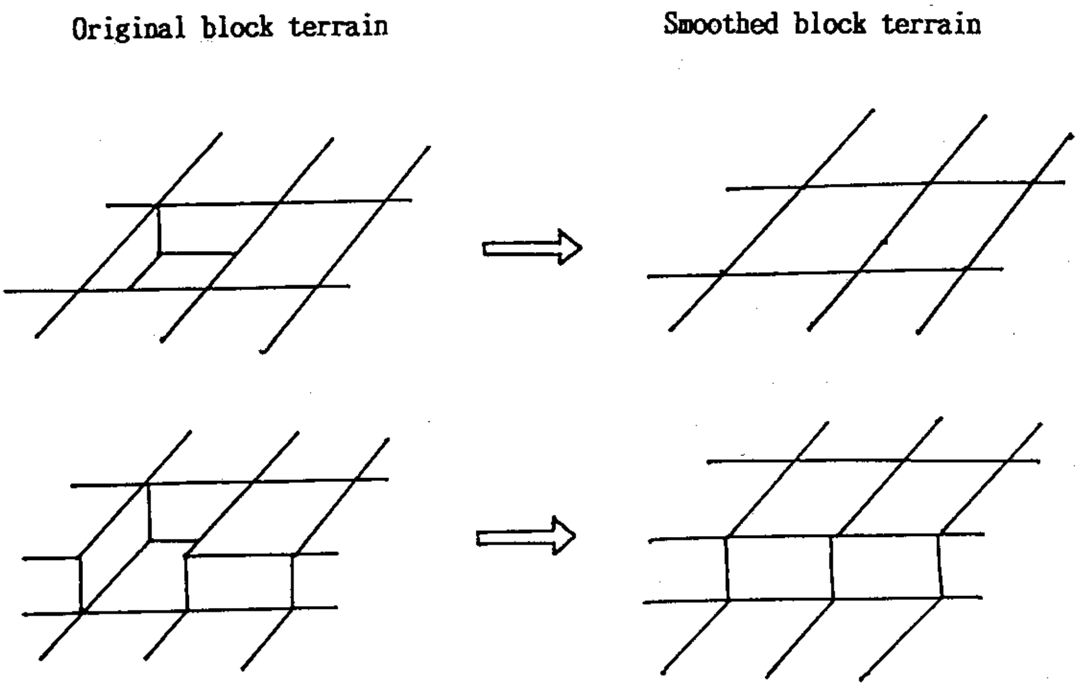


Fig. 2.14 Example of smoothing method for highly complex terrain.

3. Computational Codes

3.1 EXPRESS-I

3.1.1 Computational Flow

The flowchart of EXPRESS-I is shown in Fig. 3.1. In the figure, Sub.XX means that the processing is done in Sub.XX. Tree structure is shown in Fig. 3.2. The calculation is carried out as follows.

1. Input of parameters for calculation.
2. Input of geographical data and conversion to block topography.
3. Input of meteorological data.
4. Interpolation of observed wind data to the three-dimensional cell surfaces.
5. Calculation of $\lambda_{i,j,k}$ by iteration of Poisson's equation.
6. Calculation of mass consistent wind vectors.
7. Output of 3-D wind field.
8. Return to 3 for the next analysis or go to 9.
9. End.

3.1.2 Main Program and Subroutine

1) Main program

It controls the process from 1-9 in 3.1.1 and the flowchart is the same as Fig. 3.1.

2) Subroutine

DPMAP : Input of terrain data.
DPWET1: Input of meteorological data.
DPWIND: Output of calculated 3-D wind field.
GCONVX, GCONVY: Conversion of longitude and latitude to x-, y-coordinates (m).
NAMEL : Input of namelist data.
PCR1 : Calculation of λ_{ijk} by the MILUCR method.
PWWIND: Calculation of wind speed at the arbitrary height by power low.
RELUX : Calculation of λ_{ijk} by the SOR method.
RELUX2: Set of parameters for the MILUCR method.
TOPO0 : Conversion of terrain data HDATA to model block terrain K0 and set of the boundary condition parameter IGC for 3-D cells. IGC is a number of three figures. IGC of 999 is allotted to the cells under the ground and IGC of 111 is to the free surface cells. The first, second and third figures indicate the x-, y-

and z-direction boundary conditions, respectively. The parameters in Table 2.1 are decided based on this index.

WINDAD: Calculation of 3-D mass-consistent wind vectors (US, VS, WS) on cell surfaces and conversion of (US, VS, WS) to (UP, VP, WP) on 3-D grid points.

WIND01: Initial guess of wind vectors (US, VS, WS) on cell surfaces by the interpolation and extrapolation of observed wind data. The wind data from three observatories whose weights are heavy to the objective grid point are used for the interpolation by Eq.(1). Here, WS is set to 0.0. When the parameter ICYCL is equal to 0 in the namelist, the program calculates the highest terrain barriers between the stations and the grid points and output them in the barrier file. When the parameter ICYCL is equal to 1, the program reads the highest terrain barriers between the stations and grid points from the barrier file. By the improvement of this subroutine, another version of EXPRESS-I, named EXPRESS-IS, achieved quicker computation time, although it needs larger memory. The detail of EXPRESS-IS is described in Appendices 2.

3.1.3 Common Statement

The list of common statements used in the main program and subroutines is shown in Table 3.1.

3.1.4 Parameter Statement

The parameters which allot the dimension size to the main variables are defined by using parameter statements in the include file. The parameters are defined as follows;

KXP : the number of mesh in horizontal direction (X-direction) (=51)
KYP : the number of mesh in horizontal direction (Y-direction) (=51)
KZP : the number of mesh in vertical direction (=21)
KSP : the number of meteorological observatories (=40)

3.1.5 Fortran Statement used in the Program

The classification of Fortran statements used in the program is shown in Table 3.2.

3.2 EXPRESS-II

3.2.1 Computational Flow

The flowchart of EXPRESS-II is shown in Fig. 3.3. The tree structure is shown in Fig. 3.4. The calculation is carried out as follows.

1. Input of parameters for calculation.
2. Input of geographical data and conversion to block topography.
3. Input of physical constants of released nuclides, composition rates of nuclides of noble gases and iodines at shutdown, and KDE concentration and dose data tables.
4. Conversion of release rates at the arbitrary time to those at shutdown.
5. Zero clear of variables of concentrations and doses, and setting of the computational mesh and the time parameters.
6. Input of positions of particles which are already released, deposition, external and internal doses at the starting time of the calculation, in the case where the calculation starts from arbitrary time during the release.
7. Input of meteorological data and wind field data.
8. Calculation of decay rate, effective and averaged γ-ray energies of nuclides.
9. Data setting of particles generated during the dump interval.
10. Calculation of the transport and diffusion of particles and calculation of air concentration, deposition and air dose rate due to cloud shine.
11. Calculation of the elapsed time.
12. Output of air concentration and deposition.
13. Calculation and output of air dose rate, γ-external dose, thyroid dose and internal dose.
14. Return to 7 or go to 15.
15. Output of particle's positions and the radioactivities at the end of calculation.
16. End.

In an emergency, the calculation will be sometimes stopped tentatively to wait for the input of new meteorological data and continued again after the acquisition of new data. EXPRESS-II makes such intermittent usages possible by the functions of steps 6 and 15. The file of particle positions generated by the step 15 is used at the step 6 in the next calculation to input initial positions of particles which are already discharged. The input of deposition and external and internal doses which are output in steps 12 and 13 are needed for the time integration of them from the start of the release.

The detail of the file treatment during the intermittent use is shown in Appendices 1.

3.2.2 Main Program and Subroutine

1) Main program

It controls the process from 1-16 in 3.2.1 and the flowchart is the same as Fig. 3.3. The time parameters which are managed in the main program are shown in Fig. 3.5. IRTIM(i) and ICSTIM(i)(i=1,2) are the release starting time and the calculation starting time, respectively. i=1 means YYMMDD and i=2 HHMMSS. RTIM is the elapsed time(s) from 00:00AM to the start of release. TINT is the elapsed time(s) from the start of calculation to the start of release. RLEND is the elapsed time(s) from the start to the end of release. TRACE is the elapsed time(s) from the start to the end of calculation. WIDRC is dump interval(s). WIDRCS is the release period of particles during WIDRC (in the case of continuous release, WIDRCS = WIDRC). The present time is indicated by INTEGER IT1(YYMMDD) and IT2(HHMMSS) and CHARACTER NTIMEC (YYMMDDHHMMSS).

2) Subroutine

CIDE :	Calculation of averaged and effective γ-energies, EVMIX and EFMIX, and decay rate QREL. Extraction of exposure dose rate table (μR/h)/Bq of the objective averaged γ-energy from the KDE dose file(μR/h)/Ci.
CIDEB :	Set of block data. The several parameters in block data can be changed from the namelist. The number of particles is defined by MAXP and the period until all the particles are released is defined by TFULL. In the case where the release period is very long and the release continues after TFULL, the program uses the particles which have already gone out of the computational region as a source again. Otherwise it chooses several particles in the region randomly as a new source. However, if such random samplings are repeated, the statistical error will increase in the region far from the release point. Thus, the newly generated marker particles after TFULL had better be supplied by the recyle of old particles which have gone out of region. In the block

data, TFULL is set to 7200 sec. It is appropriate in local region, e.g. 10 km, because, for example, the particle will go out after 3600(s) after the release in the wind field of 3 m/s.

CIDE03: Set of decay constant, averaged and effective γ-energy, KDE concentration and dose tables, and isotopic composition rates of noble gases and iodines at the shutdown. Set of flag to the nuclides released (NPNT=1: mixed noble gases, 2: mixed iodines, 3: single noble gas, 4: single iodine, 5: others).

DATCHK: Control of time when the simulation is performed over next month.

DEPOSD: Calculation of a conversion factor to estimate the depositions at the shutdown. This subroutine is effective for the intermittent uses. The deposition data in the output file include the decay effect. Thus, when the deposition data in the file are input for the accumulation, the data should be converted to the values at the shutdown.

DIFFU : Calculation of horizontal and vertical diffusion coefficients at the particle position. Calculation of the transport and diffusion length of each particle.

DIVIDL: Calculation of relative relations between computational mesh and particle positions. Calculation of air concentration, deposition and air dose rate.

DOSCNV: Calculation of dose conversion factor from exposure dose rate(R) to γ-external dose (Sv) for the objective γ-energy.

DPMAP : Input of topographical data and set of terrain mesh.

DTTOS : Conversion of HHMMSS to sec.

EXDOSG: Calculation of a conversion factor from deposition (Ci/m^2) to exposure dose rate (μR/h) for the objective γ-energy. Calculation of air dose rate (nGy/h) and γ-external dose (mSv) due to ground-shine.

FPDOSE: Calculation of internal doses (mSv) due to inhalation except thyroid dose. Effective dose equivalent(ID=1) and organ dose(ID=2) are calculated under the three age classificaions.

GCONVX, GCONVY: Conversion of latitude and longitude to x- and y-coordinates (m).

GRAND : Conversion of terrain data to block topography and calculation of cell which includes the release point.

GREF : Treatment of reflection when particles migrate into the ground.

IBL : Definition of the boundary layers.

INDOSE: Calculation of thyroid doses (mSv) due to inhalation under the three age classification.

INIL : Generation of marker particles which represent the radioactivity discharged into atmosphere during WIDRC.

INPUT : Input of namelist parameters.

INTCNV: Definition of conversion factors and critical organ for internal doses (DC1: effective dose equivalent, DC2: organ dose).

ISTODT: Conversion of sec to HHMMSS.

LEVEL1: Definition of vertical diffusion coefficients on 3-D grid points.

METCO : Input of meteorological data.

METMSH: Input of 3-D wind field data.

NCCNST: Input of physical constants of the objective nuclides.

NUCCRE: Input of isotopic composition rates of noble gases and iodines in the fuel at shutdown.

PCKNG : Exclusion of particles which have gone out of region from the queue of particle ID number and renumbering of particles in the computational region.

PERCEL: Input of information of particles which were already discharged into atmosphere at the start of simulation. This subroutine is effective for intermittent uses of EXPRESS-II.

PRISE : Calculation of the wind speed at the release point and the plume rise.

RDDATA: Input of deposition, γ-external dose, thyroid dose and internal doses at the start of the calculation for the accumulation from the start of release. This subroutine is effective for intermittent use of EXPRESS-II.

REC : Output of air concentration and deposition. Air concentration ASPC and deposition DASPC which are calculated in Sub. DIVIDL are accumulated ones for WIDRC and do not include decay effect. Thus, instantaneous air concentration SPCAR(Bq/m^3) is calculated by multiplying ASPC by temporal correction factor (TSTEP/WIDRC) and decay rate QREL. Deposition for WIDRC is summed up to deposition at the start of calculation and the decay effect is considered by multiplying the sum of deposition by decay rate QREL.

RECDS : Output of air dose rate, γ-external dose, thyroid dose and internal doses. Exposure dose rate due to cloud-shine AIRDSA (μR) which is calculated in Sub. DIVIDL is accumulated one for WIDRC and does not include decay effect. Thus, air dose rate (nGy/h) is calculated by multiplying AIRDSA by temporal correction factor (WIDRC/3600), decay rate QREL and conversion factor 8.7 (nGy/μR). Air dose rate due to ground-shine is calculated in this subroutine based on deposition. γ-external dose (mSv) is calculated based on air dose rate. Thyroid and other internal doses (mSv) due to inhalation are calculated based on air concentrations at the ground surface.

RSTOUT: Output of information of particles at the end of simulation for the next simulation during the intermittent use.

SOURCE: Conversion of release rates from namelist to those at shutdown. The program assumes release rates from the namelist to be those at the calculation starting time.

TCNVLN: Conversion of YYMMDDHH to HH.

TINTVL: Calculation of the time interval ITIM (s) between ISTIME and IETIME (YYMMDDHHMMSS).

TRANP : Calculation of transport term and new position of particle at the end of time step.

XEINT : Extraction of several conversion factors of the objective γ-energy from those in the block data.

XEXIT : Output of control data for the graphics. By using these data, it is possible to read output files from EXPRESS-II.

3.2.3 Common Statement

The list of common statements used in main program and subroutines is shown in Table 3.3.

3.2.4 Parameter Statement

The parameters which allot the dimension size to the main variables are defined by using parameter statement in the included file. The parameters are defined as follows;

NNOB : the number of objective noble gases (=15)

NIOD : the number of objective iodines (=7)

NFP : the number of nuclides which the model can treat in the same time (=2)

NFPALL: the number of other nuclides (=35)

NAGE : the number of age classification (=3)

NORG : the number of internal dose classification (=2)

NEOA : NAGE*NORG (=6)

IPP : the number of particles (=2000)
IPMX : the number of terrain mesh (X-direction) (=51)
IPMY : the number of terrain mesh (Y-direction) (=51)
IPCX : the number of wind field mesh (X-direction) (=47)
IPCY : the number of wind field mesh (Y-direction) (=47)
IPCZ : the number of mesh in vertical direction (=22)*
NCELX : the number of concentration cell (X-direction) (=46)
NCELY : the number of concentration cell (Y-direction) (=46)

* IPCZ must be KZP+1, where KZP is a parameter of EXPRESS-I.

3.2.5 Fortran Statement used in the Program

The classification of Fortran statements used in the program is shown in Table 3.4.

3.3 Input/Output

The files relating to EXPRESS-I and -II are shown in Fig. 3.6.

3.3.1 Namelist

The data input from the namelists can be divided into two types. The first is essential data which must be set for practical uses and the second is research-purpose data which can be omitted in practical uses. The programs have default values for the second type of data. When the input of second type of data from the namelist is neglected in the practical stage, the programs use default data.

(1) Namelist for EXPRESS-I

Input subroutine: NAMEL

NAMESP(2)	2(C*8)	site name
ISTRDP	I*4	calculation starting date(YYMMDD)
ISTRTP	I*4	calculation starting time(HHMMSS)
ITINTP	I*4	calculation period(HHMMSS)
IDMPIP	I*4	dump interval(HHMMSS)
KMAX	I*4	mesh number of z-direction
DZ	R*4	mesh width of z-direction(m)
ICYCL	I*4	1: terrain barrier file input, 0: calculation

The parameters below the line (KMAX, etc.) have default values as block data in subroutine NAMEL. Thus, users can omit to set them in the namelists, as long as defaults are used. Default values are as follows.

Parameter	Default value
KMAX	21
DZ	50.0 m
ICYCL	1

(2) Namelist for EXPRESS-II

Input subroutine: INPUT

ASITE(2)	2(C*8)	site name
IRTIM(2)	2(I*4)	release starting date IRTIM(1)(YYMMDD), time IRTIM(2)(HHMMSS)
IENTIM(2)	2(I*4)	release end date IENTIM(1)(YYMMDD), time IENTIM(2)(HHMMSS)*
RLAT	R*4	latitude of release point(degree)
RLONG	R*4	longitude of release point(degree)
Z00	R*4	release height above the ground level(m)
ICSTIM(2)	2(I*4)	calculation starting date ICSTIM(1)(YYMMDD), time ICSTIM(2)(HHMMSS)
IWIDRC	I*4	output(dump) interval(HHMMSS)**
ITRACE	I*4	tracing time interval(HHMMSS)
ISDTIM(2)	2(I*4)	shutdown date ISDTIM(1)(YYMMDD) and time ISDTIM(2)(HHMMSS)
REACT	C*8	reactor type(BWR/PWR)
NCLID	I*4	the number of nuclides released(max=2)
NAME(2)	2(C*8)	names of nuclides***
RRATE(2)	2(R*4)	release rates of nuclides(Bq/h)
ZMW	R*4	mesh width of z-direction(m)(=DZ in EXPRESS-I)**
NMZ	I*4	vertical mesh number(=KMAX in EXPRESS-I)**
BOND(2)	2(R*4)	height of boundary layers(m)
NSL(3)	3(C*8)	turbulence condition in boundary layers(A-F)
BURNUP	R*4	burnup rate(MWD/Ut)
TE	R*4	temperature of environment(degree)
TS	R*4	temperature of gas(degree)
WE	R*4	emission velocity(m/s)
RADS	R*4	stack radius(m)
SIGHO	R*4	horizontal standard deviation of source(m)****
SIGZO	R*4	vertical standard deviation of source(m)

* : Only when users cannot know the end time of release, they can omit the set of IENTIM. In this case, the code assumes continuous release during the interval of ITRACE.

** : IWIDRC, ZMW and NMZ should be the same as IDMPIP, DZ and KZ in the namelist of EXPRESS-I, respectively.

*** : Nuclides which are available to EXPRESS-II are shown in Table 3.5.

****: By the set of SIGHO and SIGZO, homogeneous elliptic volume source with standard deviations of SIGHO and SIGZO is assumed.

The parameters below the line(NCLIDE, etc.) have default values as block data in subroutine CIDEB. Thus, users can omit to set them in the namelists, as long as defaults are used. The default values are as follows.

Parameter	Default value
IENTIM(2)	999999, 999999
NCLID	2
NAME(2)	'NOBLE', 'IODINE'
BRATE(2)	1.0, 1.0
ZMW	50.0
NMZ	21
BOND(2)	2000.0, 2000.0
NSL(3)	'D', 'D', 'F'
BURNUP	10000.0
TE	0.0
TS	0.0
WE	0.0
RADS	5.0
SIGHO	0.0
SIGZO	0.0

When all the default values related to source data are effective, the condition of continuous unit release of noble and iodine gases from the point source without plume rise is assumed.

Example of namelists of EXPRESS-I and -II is shown in Fig. 3.7.

3.3.2 Input and Output Files

(1) Geological File

Input subroutine: DPMAP(EXPRESS-I, EXPRESS-II)

ISNAME, SLT, SLG, RZLG, RZLT, ALLG, ALLT, NMLG, NMLT	2X, 2A8, 6E15.7, 2I5	site name latitude, longitude of map origin(deg.) lower-left corner of map from origin(x,y)(km) lengths of x- and y-coordinates(km) the number of x- and y-direction meshes
HT(I,J)	*	terrain height of cell(I,J)(m)

* Map origin is used as the origin of computational region. See Fig. 2.12 for visible understanding of parameters. Example of geological file is shown in Fig. 3.8.

(2) Physical Constant File

Input subroutine: NCCNST(EXPRESS-II)

NCDMY(J), DECAY(J), EFGME(J), AVGME(J)	A8, 3E15.7	name of nuclide J decay constant of nuclide J(s^{-1}) effective energy of γ rays from nuclide J(MeV) averaged energy of γ rays from nuclide J(MeV)

J=57 (noble gases 15 + iodine isotope 7 + other nuclides 35)

(3) Nuclide Composition File

Input subroutine: NUCCRE(EXPRESS-II)

REACIN	A8	reactor type(BWR/PWR)
BURN(IJ)	E15.7	burnup ratio(MWD/Ut)
AP(IJ,N)	22(/E15.7)	composition ratio of noble gases and iodines

Data are stored from REACIN to AP for BWR and PWR. BURN is divided into 22(IJ) from 2000 to 50000. For each IJ, the composition ratio AP(IJ,N) of 22(N) nuclides (noble gases 15 and iodines 7) are stored. The summation of AP(IJ,N) of noble gases and iodines are 1, respectively.

(4) KDE Concentration File

Input subroutine: CIDE03(EXPRESS-II)

PFCONC	*	KDE concentration data(m^{-3})
PFDEPO	*	KDE wet deposition data(m^{-2})

PFCONC, PFDEPO are stored by the order of

(((PFCONC(I,J,K),I=1,11),J=1,41),K=1,11),((PFDEPO(I,J),I=1,11),J=1,41).

(5) KDE Dose File

Input subroutine: CIDE03(EXPRESS-II)

PFDOSE	*	KDE exposure dose rate data(μR/h)/Ci

PFDOSE is stored by the order of (((PFDOSE(L,I,J,K),L=1,17),I=1,11), J=1,10),K=1,5).

(6) Meteorological Data File

Input subroutine: DPWET1(EXPRESS-I), METCO(EXPRESS-II)

NSTN	I3	the number of observatories
NASTN,IDSTN	A16,I3,	name of observatory, sequential number,
STLT,STLG,STHGT,	3F10.0,	latitude, longitude(deg.), height above ground(m) of observatory
IDSN	I3	flag for vertical profile data at the same point*
NTIMEW	A12	observed time(YYMMDDHHMMSS)
WINDD,WINDV, RAIN,STAB	4F10.0	wind direction(NNE=1,...,N=16)**, wind speed(m/s), precipitation(mm/h), atmospheric stability(1(A)-6(F))

* Only when the observatories whose heights are different are prepared at the same location for the measurement of wind profile, IDSN must be set to show that the observatories provide wind profile at one location. The same value(except 0) of IDSN should be set for all the observatories at the same location. If vertical profiles are provided from several locations, the different values of IDSN should be used against each location. (See example of meteorological data in Fig. 3.9)

** If wind direction is supplied in the unit of degree, the values should be divided by 22.5. For example, the value of 1.333 should be set as WINDD against the wind direction of 30 degrees.

The order of observed data are from WINDD(1)-STAB(1),...,WINDD(NSTN)-STAB(NSTN). Data lack and no-measurement should be shown in -999 and -888, respectively. Temporal observed data are stored by the repeat from NTIMEW to STAB.

(7) Terrain Barrier File

Input and output subroutine: WIND01(EXPRESS-I)

GTOP(N,I,J,IXY)	*	maximum height on the line between observatory and interpolation point

GTOP are stored by the order of (((GTOP(N,I,J,IXY),N=1,NSTMAX),I=2,IMAX), J=2,JMAX),IXY=2), where NSTMAX: the number of observatories, IMAX,JMAX: the numbers of interpolation points in x- and y-directions and IXY: flag, 1: terrain barrier for u-component, 2: for v-component. Because the interpolation points for u- and v-components in the staggered scheme are different as shown in Fig. 2.6, GTOP are prepared for u- and v-component interpolation, respectively. When ICYCL=0 in the namelist of EXPRESS-I, this file is made in the EXPRESS-I calculation. Thus, when EXPRESS-I is firstly applied to the objective site, ICYCL should be 0 and, after that, ICYCL should be 1. By the set of ICYCL=1, the CPU time will be reduced.

(8) Wind Field File

Output subroutine: DPWIND(EXPRESS-I)

Input subroutine : METMSH(EXPRESS-II)

NAMEST,	2A8,	site name
SLT,SLG,	4E15.7,	latitude, longitude of origin(deg.)
X000,Y000,		lower-left corner of wind mesh(km)
NMX,NMY,NMZ	3I5,	number of meshes in x-, y- and z-directions
DX,DY,DZ	3E12.5	width of meshes in x-, y- and z-directions
TIMEW	A12	calculated time(YYMMDDHHMMSS)
US(I,J,K)	*	wind vectors in x-direction(m/s)
VS(I,J,K)	*	wind vectors in y-direction(m/s)
WS(I,J,K)	*	wind vectors in z-direction(m/s)

US,VS,WS are stored by the order of (((US(I,J,K), or [VS(I,J,K),S(I,J,K),] I=1,NMX),J=1,NMY),K=1,NMZ). Calculated winds are stored by the repeat from TIMEW to WS.

(9) Air Concentration File

Output subroutine: REC(EXPRESS-II)

Input subroutine : RDDATA(EXPRESS-II)

NTIMEC	A12	calculated time(YYMMDDHHMMSS)
NAME	A8	nuclide name
SPCAR(IMJ,NN)	*	concentration (Bq/m^3)

SPCAR are stored by the order of ((SPCAR(I,J,NN),I=1,NCX),J=1,NCY). When the number of nuclides NN is two, data are stored by the repeat of NAME and SPCAR after NTIMEC. The input of file in Sub. RDDATA is to find the end of file for the next dump and has no meanings for calculations.

(10) Deposition File

Output subroutine: REC(EXPRESS-II)
Input subroutine : RDDATA(EXPRESS-II)

NTIMEC	A12	calculated time(YYMMDDHHMMSS)
NAME	A8	nuclide name
SPCDP(I,J,NN)	*	deposition(Bq/m^2)

SPCDP are stored by the format of ((SPCDP(I,J,NN),I=1,NCX),J=1,NCY). When the number of nuclides NN is two, the data are stored by the repeat of NAME and SPCDP.

(11) Air Dose Rate File

Output subroutine: RECDS(EXPRESS-II)
Input subroutine : RDDATA(EXPRESS-II)

NTIMEC	A12	calculated time(YYMMDDHHMMSS)
AIRDST(I,J)	*	air dose rate(nGy/h)
AIRDSA(I,J,NN)	*	air dose rate due to nuclide NN(nGy/h)

AIRDST and AIRDSA are stored by the order of ((AIRDST(I,J),I=1,NCX),J=1, NCY),(((AIRDSA(I,J,NN),I=1,NCX),J=1,NCY),NN=1,NC), where NCX,NCY,NC are the numbers of cells in x- and y-directions and nuclides, respectively. The input of file is only to find the end of file.

(12) γ-External Dose File

Output subroutine: RECDS(EXPRESS-II)
Input subroutine : RDDATA(EXPRESS-II)

NTIMEC	A12	calculated time(YYMMDDHHMMSS)
EXTDST(I,J)	*	γ-external dose(mSv)
EXTDSA(I,J,NN)	*	γ-external dose due to nuclide NN(mSv)

The order for EXTDST and EXTDSA is the same as AIRDST and AIRDSA.

(13) Thyroid Dose File

Output subroutine: RECDS(EXPRESS-II)

Input subroutine : RDDATA(EXPRESS-II)

NTIMEC	A12	calculated time(YYMMDDHHMMSS)
THYDSA(I,J,IJ)	*	thyroid dose for age group IJ(mSv)

THYDSA is stored by the order of (((THYDSA(I,J,IJ),I=1,NCX),J=1,NCY), IJ=1,NAGE), where NCX,NCY,NAGE(=3) are the numbers of cells in x- and y-directions and age group, respectively.

(14) Internal Dose File

Output subroutine: RDDATA(EXPRESS-II)

Input subroutine : RECDS(EXPRESS-II)

NTIMEC	A12	calculated time(YYMMDDHHMMSS)
NAME,CORGN(NONUC)	2A8	nuclide name and organ
INTDSA(I,J,IJ,L,NONUC)	*	internal dose(mSv) due to nuclide NONUC for age group IJ L=1: effective dose equivalent L=2: organ dose

INTDSA is stored by the format of ((((INTDSA(I,J,K,L,NONUC),I=1,NCX), J=1,NCY),IJ=1,NAGE),L=1,NORG). When the number of nuclides NONUC related to internal doses is two, the data are stored by the repeat of NAME and INTDSA.

(15) Particle File

Input subroutine : PERCEL(EXPRESS-II)

Output subroutine: RSTOUT(EXPRESS-II)

NTIMEC,	A12,	output time(YYMMDDHHMMSS)
NPLST	I7	the number of particles
X(I),Y(I),Z(I),	3E15.7,	position of particle I(m)
IRCY(I),NSTL(I)	2I3	ID flag, atmospheric stability at the particle position
PDT(I),(Q(I,J),J=1,2)	3(E15.7,1X)	travel distance(m) and radio-activity(Bq) J: nuclide number

(16) Output Data Information File

Output subroutine: XEXIT(EXPRESS-II)

SLG,SLT,	*	longitude, latitude of origin(deg.)
XMTMIN,YMTMIN,		lower-left corner of wind mesh(km)
NMX,NMY,NMZ,		number of meshes in x-, y- and z-directions
XMW,YMW,ZMW		width of meshes in x-, y- and z-directions
SLG,SLT,	*	longitude, latitude of origin(deg.)
XCOMIN,YCOMIN,		lower-left corner of Conc. mesh(km)
NCX,NCY,		number of Conc. meshes in x- and y-directions
XMW,YMW		width of Conc. meshes in x- and y-directions
NCLID,	*	nuclide number treated
(NAME(NN),NN=1,NCLID),		nuclide name
NONUC		nuclide number related to internal doses

Table 3.1 Subprogram name vs. Common block name.

```
              ==== SUBPROGRAM NAME  VS.  COMMON BLOCK NAME ====
+--------------+----------------+
I**************IDDDGG.MNPPR.RTWWI
I**************IPPPCC.AACWE.EOIII
I**************IMWWNN.IMRWL.LPNNI
I**************IAEIVV.NE1IU.UODDI
I**************IPTNXY. L NX.XOAOI
I**************I 1D  .   D .2 D1I
+--------------+----------------+
I    1./BARIA / I     . X   .   XI
I    2./BL1   / IX X  .XXX X.XXXXI
I    3./BL1D  / I  X  .X X X.X XXI
I    4./DIVDT / I     .  X X.X   I
I    5./DPCOMM/ IXXX  .XX   .    I
I..............I................I
I    6./EPSZ  / I     .  X  .X   I
I    7./GDATA / IX X  .     .    I
I    8./MAPDT / IX XXX.X    . X XI
I    9./MDFLG / I X   .     .   XI
I   10./MTNAME/ I X   .     .   XI
I..............I................I
I   11./STDATA/ I X   .X    .   XI
I   12./STNAM / I  X  . X   .    I
I   13./SYSPIO/ I     .     .   XI
I   14./TCONTP/ I     .XX   .    I
I   15./WINDDT/ I X   .X    .   XI
I..............I................I
I   16./WINDOB/ I X   .XX   .   XI
I   17./WORK  / I     .  X  .X   I
+--------------+----------------+
```

Table 3.2 Classification of Fortran statements of wind field model.

```
============================================================================================================
I         T H E   C L A S S I F I C A T I O N   O F   F O R T R A N   S T A T E M E N T S                  I
============================================================================================================
I    COMMENT            400( 26.86 %)                 X          WAIT                  0(  0.0  %)         I
I    CONTINUATION       193( 12.96 %)                 X          INQUIRE               0(  0.0  %)         I
I    ASSIGNMENT         343( 23.04 %)                 X          COMPLEX               0(  0.0  %)         I
I    ASSIGN               0(  0.0  %)                 X          LOGICAL               0(  0.0  %)         I
I    GO TO                4(  0.27 %)                 X          INTEGER               0(  0.0  %)         I
I    ASSIGNED GO TO       0(  0.0  %)                 X          CHARACTER             9(  0.60 %)         I
I    COMPUTED GO TO       0(  0.0  %)                 X          DOUBLE PRECISION      0(  0.0  %)         I
I    ARITHMETIC IF        0(  0.0  %)                 X          REAL                 14(  0.94 %)         I
I    LOGICAL IF         100(  6.72 %)                 X          EQUIVALENCE           0(  0.0  %)         I
I         ASSIGNMENT      67    PRINT               0 X          DATA                 12(  0.81 %)         I
I         ASSIGN           0    PUNCH               0 X          NAMELIST              1(  0.07 %)         I
I         GO TO           33    REWIND              0 X          IMPLICIT              0(  0.0  %)         I
I         ASSIGNED GO TO   0    FIND                0 X          PARAMETER            21(  1.41 %)         I
I         COMPUTED GO TO   0    WAIT                0 X          COMMON               38(  2.55 %)         I
I         ARITHMETIC IF    0    CALL                0 X          SAVE                  0(  0.0  %)         I
I         OPEN             0    RETURN              0 X          DIMENSION             3(  0.20 %)         I
I         CLOSE            0    STOP                0 X          EXTERNAL              0(  0.0  %)         I
I         READ             0    PAUSE               0 X          INTRINSIC             0(  0.0  %)         I
I         WRITE            0    DECODE              0 X          DEFINE FILE           0(  0.0  %)         I
I         BACKSPACE        0    ENCODE              0 X          PROGRAM               0(  0.0  %)         I
I         ENDFILE          0    INQUIRE             0 X          BLOCKDATA             0(  0.0  %)         I
I    IF (...) THEN       25(  1.68 %)                 X          FUNCTION              3(  0.20 %)         I
I    DO                  92(  6.18 %)                 X          SUBROUTINE           10(  0.67 %)         I
I    DO   UNTIL(...)      0(  0.0  %)                 X          ENTRY                 0(  0.0  %)         I
I    DO   WHILE(...)      0(  0.0  %)                 X          CALL                  9(  0.60 %)         I
I    ELSE                14(  0.94 %)                 X          RETURN               14(  0.94 %)         I
I    ELSE IF              0(  0.0  %)                 X          STOP                  3(  0.20 %)         I
I    END IF              25(  1.68 %)                 X          PAUSE                 0(  0.0  %)         I
I    FORMAT              23(  1.54 %)                 X          END                  14(  0.94 %)         I
I    OPEN                 0(  0.0  %)                 X          CONTINUE             72(  4.84 %)         I
I    CLOSE                0(  0.0  %)                 X          DECODE                0(  0.0  %)         I
I    READ                13(  0.87 %)                 X          ENCODE                0(  0.0  %)         I
I    WRITE               34(  2.28 %)                 X          DEBUG                 0(  0.0  %)         I
I    BACKSPACE            0(  0.0  %)                 X          AT                    0(  0.0  %)         I
I    ENDFILE              0(  0.0  %)                 X          DISPLAY               0(  0.0  %)         I
I    PRINT                0(  0.0  %)                 X          INIT                  0(  0.0  %)         I
I    PUNCH                0(  0.0  %)                 X          TRACE                 0(  0.0  %)         I
I    REWIND               0(  0.0  %)                 X          -- ROGUE --           0(  0.0  %)         I
I    FIND                 0(  0.0  %)                 X          NCHARACTER (JEF)      0(  0.0  %)         I
============================================================================================================

                                       TOTAL STATEMENTS =   1489
```

Table 3.3 Subprogram name vs Common block name of concentration and dose calculation code.

```
              ==== SUBPROGRAM NAME  VS.  COMMON BLOCK NAME ====
+--------------+--------------------------------------------------+
I**************IBCCDD.DDDDD.DEFGG.GGIII.IIILM.MMNNX.PPPRR.RRSTT.TXI
I**************ILIIAC.EIIOP.TXPCC.RRBNN.NNSEA.EECUE.CERDE.ESOCI.REI
I**************IODDTZ.PFVSM.TDDNN.AELDI.PTTVI.TTCCX.KRIDC.CTUNN.AII
I**************ICEEC .OFICA.OOOVV.NF OL.UCOEN.CMNCI.NCSA .DORVT.NNI
I**************IK OH .SUDNP.SSSXY.D  S .TNDL .OSSRT.GEET .SUCLV.PTI
I**************ID 3K .D LV . GE  .   E . VT1 . HTE . L A . TENL.  I
+--------------+--------------------------------------------------+
I   1./AME   / I     .     .     .     .     .X    .  X  .     .  I
I   2./CIDC02/ I  X  .     .     .     .X    .     .     .     .  I
I   3./CIDV01/ IXXX  .X    .     .     .X    .     .     .  X  .  I
I   4./CIDV02/ I X   .     .     .     .     .     .     .X    .  I
I   5./CIDV03/ I XX  .X    .     .     .     .     .   XX.X X  .  I
I..............I..................................................I
I   6./CIDV05/ I XX  .X    .     .     .     .     .     .  X  .  I
I   7./CIDV07/ I     .     .     .     .     .     .    X.X    .  I
I   8./CIDV09/ I     .     .     .     .     .     .   X .X    .  I
I   9./CLSPC / I     .  X X.     .     .     .     .     .     .  I
I  10./CRTORG/ IX    .     .     .     . X   .     .     .     .  I
I..............I..................................................I
I  11./DDP   / I     .     .     .     .X    .X    .     .  X  .  I
I  12./DEPOI / I     .     .     .     .     .     .   XX.     .  I
I  13./DPA   / I     .  X  .     .     .    X.     .    X.     .  I
I  14./DPCOM2/ I X   .     .     .     .    X.XX   .  X X.XX   .  I
I  15./DPDAT / IX    .     .     .     .X    .     .     .     .  I
I..............I..................................................I
I  16./DPS   / I     .  X  .     .     .X    .X    .     .     .  I
I  17./DPTOP / I     .     .     .     .X    .     . X X .     .  I
I  18./DSCNV / I X   .     . X   .     .     .     .     .X    .  I
I  19./ENERGY/ I X   .  X  .     .     .     .     .    X.X    .  I
I  20./ENNUM / IXX   .   X . X   .     .     .     .     .     . XI
I..............I..................................................I
I  21./EXIT  / IX    .     .     .X   X.X   X.     .  X  .     .  I
I  22./GAMCNV/ IX    .     . X   .     .     .     .     .     .  I
I  23./GDIF  / I     . X   .     .     .   X .     .     .     .  I
I  24./INV   / IX    . X   .     .X X  .X   X.X    .  X  .     .  I
I  25./ISG   / IX    . X   .     .    X.X   X.     .     .     .  I
I..............I..................................................I
I  26./LYR   / IX    .     .     .     .X    .     .     .     .  I
I  27./MAWIN / I     .    X.   XX.     .     .    X.     .     .  I
I  28./MESHCO/ I     .  X  .     .     .    X.     .    X.     .  I
I  29./MESHWI/ I     . X   .     . X   .    X.     .  X  .     .X I
I  30./MPINT / I     .     .     .     .X    .X    .     .     .  I
I..............I..................................................I
I  31./MSHCO / I     .  X X.     .X    .    X.    X.   XX.X    .  I
I  32./MSHMX / I     .    X.     .     .    X.     .     .     .X I
I  33./MSHWD / IX    . XX X.     .XXX  .X  XX. X  X.    X.     .X I
I  34./NCINH / I     .     .     .     .     .    X.     .X    .  I
I  35./NUCLV1/ IXXX  .     .     .     .XX   .  X  .     .     .  I
I..............I..................................................I
```

Table 3.3 (Continued)

```
                   ==== SUBPROGRAM NAME  VS.  COMMON BLOCK NAME ====
+--------------+---------------------------------------------------+
I**************IBCCDD.DDDDD.DEFGG.GGIII.IIILM.MMNNX.PPPRR.RRSTT.TXI
I**************ILIIAC.EIIOP.TXPCC.RRBNN.NNSEA.EECUE.CERDE.ESOCI.REI
I**************IODDTZ.PFVSM.TDDNN.AELDI.PTTVI.TTCCX.KRIDC.CTUNN.AII
I**************ICEEC .OFICA.OOOVV.NF OL.UCOEN.CMNCI.NCSA .DORVT.NNI
I**************IK OH .SUDNP.SSSXY.D  S .TNDL .OSSRT.GEET .SUCLV.PTI
I**************ID 3K .D LV . GE  .   E . VT1 . HTE . L A . TENL.  I
+--------------+---------------------------------------------------+
I  36./NUCLV2/ I XX  .X    .     .     .     .  X  .     .  X  .  I
I  37./NUCLV3/ I XX  .X    .     .     .     .     .     .  X  .  I
I  38./NUCLV4/ IX    .     .     .     . X   .     .     .     .  I
I  39./PAR   / IX    .     .     .    X.X   X.     .     .     .  I
I  40./PLACE / I     . XX  .     . X  X.    X.     .XX   . X   .X I
I..............I..................................................I
I  41./PNUM  / I     .     .     .    X.    X.     .XX   . X   .  I
I  42./RESO  / I     .  X  .     . X  X.    X.     .XX   . X   .X I
I  43./RLPNT / I     .     .     .X    .X    .     .     .     .  I
I  44./RLTIM / IX    .     .     .     .X   X.     .     .  X  .  I
I  45./RNTGN / I     .  X  .     .     .    X.     .     .X    .  I
I..............I..................................................I
I  46./SCMT  / I     .     .     .    X.    X.     .  X  .     .  I
I  47./SFLAG / IXXX  .X X  .     .    X.X   X.X   X.   XX.X X  .  I
I  48./SHIFT / I     .    X.     .X    .     .     .     .     .  I
I  49./SRC   / I     .  X  .     .    X.    X.     .XX   . X   .X I
I  50./STBL  / I     . X   .     .     .    X.     .     .     .  I
I..............I..................................................I
I  51./STP   / I     . XX  .     .    X.    X.X    .  X X.X    .  I
I  52./STPI  / IX    .     .     .     .X   X.     .     .     .  I
I  53./SYSIO / I     .  X  .     .X X  .    X.     .  X X.     .  I
I  54./TMCHK / I     .     .     .     .X   X.     .     .     .  I
I  55./TMPRO / I     .     .     .  X  .   X .     .     .     .  I
I..............I..................................................I
I  56./TOPG  / I     . XX  .     .XX   .   X .     .     .     .  I
I  57./TRCT  / IX    .     .     .     .X   X.     .     .     .  I
I  58./TRVL  / I     . X   .     .    X.    X.     .XX   . X   .  I
I  59./UNICNC/ I  X  .  X  .     .     .     .     .     .     .  I
I  60./UNIDS / I XX  .     .     .     .     .     .     .     .  I
I..............I..................................................I
I  61./UNIDS1/ I X   .  X  .     .     .     .     .     .     .  I
I  62./WIND  / I     .     .     .     .   XX. X   .  X  .     .X I
I  63./WOM   / IXX   .X    .     .     .X   X.     .    X.X    .  I
+--------------+---------------------------------------------------+
```

Table 3.4 Classification of Fortran statements of concentration and dose calculation code.

```
===============================================================================================================
I         T H E   C L A S S I F I C A T I O N   O F   F O R T R A N   S T A T E M E N T S                    I
===============================================================================================================
I    COMMENT           1433( 35.74 %)                  X          WAIT                 0(  0.0  %)            I
I    CONTINUATION       254(  6.34 %)                  X          INQUIRE              0(  0.0  %)            I
I    ASSIGNMENT         728( 18.16 %)                  X          COMPLEX              0(  0.0  %)            I
I    ASSIGN               0(  0.0  %)                  X          LOGICAL              0(  0.0  %)            I
I    GO TO               59(  1.47 %)                  X          INTEGER              7(  0.17 %)            I
I    ASSIGNED GO TO       0(  0.0  %)                  X          CHARACTER           37(  0.92 %)            I
I    COMPUTED GO TO       0(  0.0  %)                  X          DOUBLE PRECISION     0(  0.0  %)            I
I    ARITHMETIC IF        0(  0.0  %)                  X          REAL                 8(  0.20 %)            I
I    LOGICAL IF         154(  3.84 %)                  X          EQUIVALENCE          0(  0.0  %)            I
I         ASSIGNMENT        59   PRINT              0  X          DATA                36(  0.90 %)            I
I         ASSIGN             0   PUNCH              0  X          NAMELIST             1(  0.02 %)            I
I         GO TO             91   REWIND             0  X          IMPLICIT             0(  0.0  %)            I
I         ASSIGNED GO TO     0   FIND               0  X          PARAMETER           86(  2.15 %)            I
I         COMPUTED GO TO     0   WAIT               0  X          COMMON             266(  6.64 %)            I
I         ARITHMETIC IF      0   CALL               1  X          SAVE                 0(  0.0  %)            I
I         OPEN               0   RETURN             0  X          DIMENSION           21(  0.52 %)            I
I         CLOSE              0   STOP               0  X          EXTERNAL             0(  0.0  %)            I
I         READ               0   PAUSE              0  X          INTRINSIC            0(  0.0  %)            I
I         WRITE              3   DECODE             0  X          DEFINE FILE          0(  0.0  %)            I
I         BACKSPACE          0   ENCODE             0  X          PROGRAM              0(  0.0  %)            I
I         ENDFILE            0   INQUIRE            0  X          BLOCKDATA            1(  0.02 %)            I
I    IF (...) THEN       54(  1.35 %)                  X          FUNCTION             6(  0.15 %)            I
I    DO                 165(  4.12 %)                  X          SUBROUTINE          34(  0.85 %)            I
I    DO   UNTIL(...)      0(  0.0  %)                  X          ENTRY                0(  0.0  %)            I
I    DO   WHILE(...)      0(  0.0  %)                  X          CALL                43(  1.07 %)            I
I    ELSE                34(  0.85 %)                  X          RETURN              42(  1.05 %)            I
I    ELSE IF             10(  0.25 %)                  X          STOP                 6(  0.15 %)            I
I    END IF              54(  1.35 %)                  X          PAUSE                0(  0.0  %)            I
I    FORMAT              83(  2.07 %)                  X          END                 42(  1.05 %)            I
I    OPEN                 0(  0.0  %)                  X          CONTINUE           214(  5.34 %)            I
I    CLOSE                0(  0.0  %)                  X          DECODE               0(  0.0  %)            I
I    READ                37(  0.92 %)                  X          ENCODE               0(  0.0  %)            I
I    WRITE               93(  2.32 %)                  X          DEBUG                0(  0.0  %)            I
I    BACKSPACE            0(  0.0  %)                  X          AT                   0(  0.0  %)            I
I    ENDFILE              0(  0.0  %)                  X          DISPLAY              0(  0.0  %)            I
I    PRINT                0(  0.0  %)                  X          INIT                 0(  0.0  %)            I
I    PUNCH                0(  0.0  %)                  X          TRACE                0(  0.0  %)            I
I    REWIND               1(  0.02 %)                  X          -- ROGUE --          0(  0.0  %)            I
I    FIND                 0(  0.0  %)                  X          NCHARACTER (JEF)     0(  0.0  %)            I
===============================================================================================================

                                      TOTAL STATEMENTS =   4009
```

Table 3.5 Nuclides which can be treated in the model.

Noble Gases

```
  DATA          ( SPNMN( I ), I = 1, 15 )
 1          / 'KR83M    ','KR85     ','KR85M    ','KR87     ','KR88     ',
 2            'KR89     ','KR90     ','XE131M   ','XE133    ','XE133M   ',
 3            'XE135    ','XE135M   ','XE137    ','XE138    ','XE139    '/
```

Iodine

```
  DATA          ( SPNMI( I ), I = 1, 7  )
 1          / 'I129     ','I131     ','I132     ','I133     ','I134     ',
 2            'I135     ','I136     '/
```

Other nuclides

```
  DATA          ( SPNMF( I ), I = 1, 35 )
 1          / 'RB86     ','SR89     ','SR90     ','Y90      ','Y91      ',
 2            'ZR95     ','NB95     ','NB95M    ','RU103    ','RU106    ',
 3            'RH106    ','AG111    ','CD115    ','SN123    ','SN125    ',
 4            'SB125    ','SB127    ','TE127M   ','TE127    ','TE129M   ',
 5            'TE129    ','TE132    ','CS136    ','CS137    ','BA140    ',
 6            'LA140    ','CE141    ','PR143    ','CE144    ','PR144    ',
 7            'ND147    ','PM147    ','SM151    ','EU155    ','EU156    '/
```

Mixed gas　　NOBLE　　IODINE

(mixed noble gases)　　(mixed iodines)

Non-radioactive gas　　SF6

(Tracer gas for field experiment)

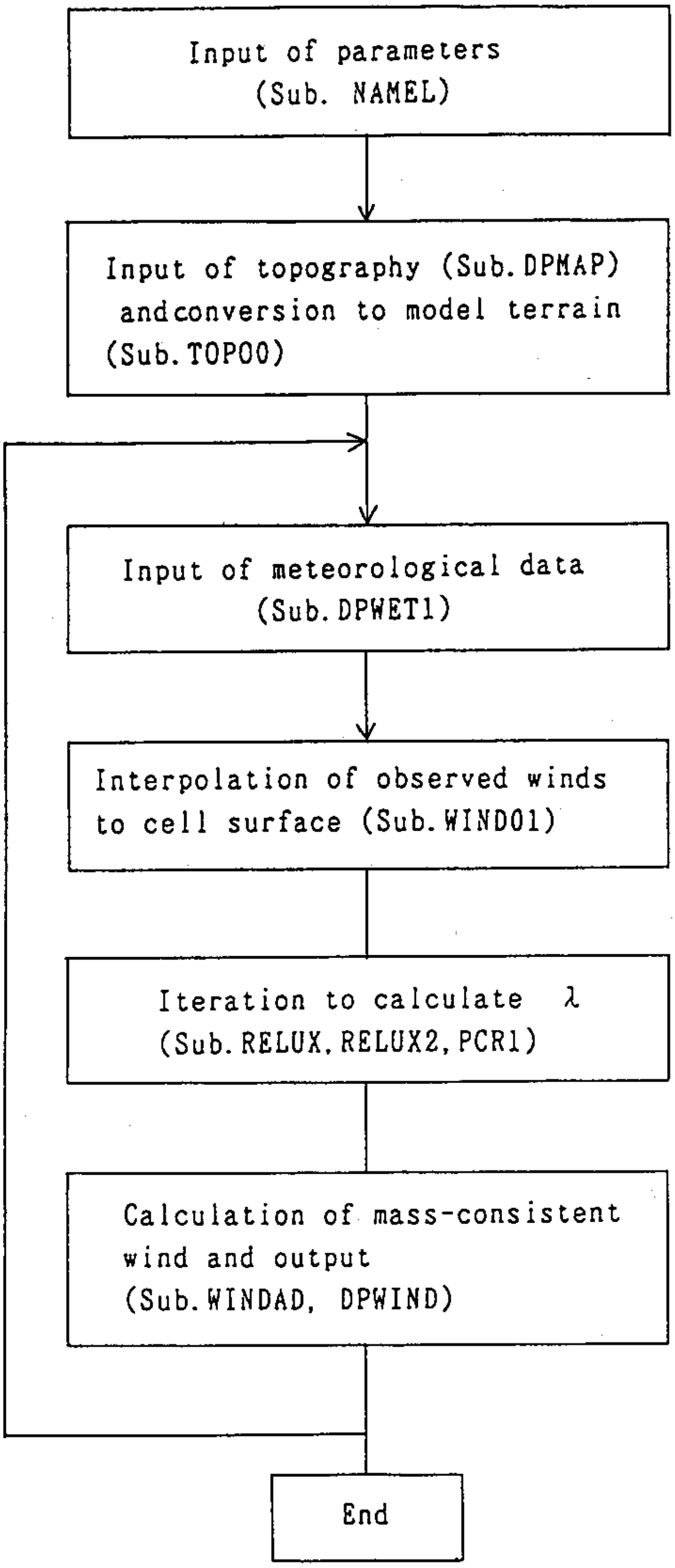


Fig. 3.1 Flow chart of wind field calculation code.

```
MAIN  -----NAMEL ----*MOD
        +--DPMAP ----*FLOAT
        +--TOPO0 ----*INT
        I          +-*MIN
        +--DPWET1----*INT
        +--WIND01----*COS
        I          +-*SIN
        I          +--GCNVX ----*TAN
        I          I          +-*SIN
        I          +--GCNVY ----*TAN
        I          I          +-*COS
        I          I          +-*SIN
        I          +-*INT
        I          +-*FLOAT
        I          +-*ABS
        I          +-*MAX0
        I          +-*ALOG10
        I          +-*EXP
        I          +--PWWIND
        +--RELUX2----*DBLE
        I          +-*MOD
        I          +--PCR1
        +--WINDAD----*MAX0
        I          +-*MOD
        I          +-*MIN0
        +--DPWIND----*FLOAT
        +-*MOD
```

Fig. 3.2 Tree structure of wind field calculation code.

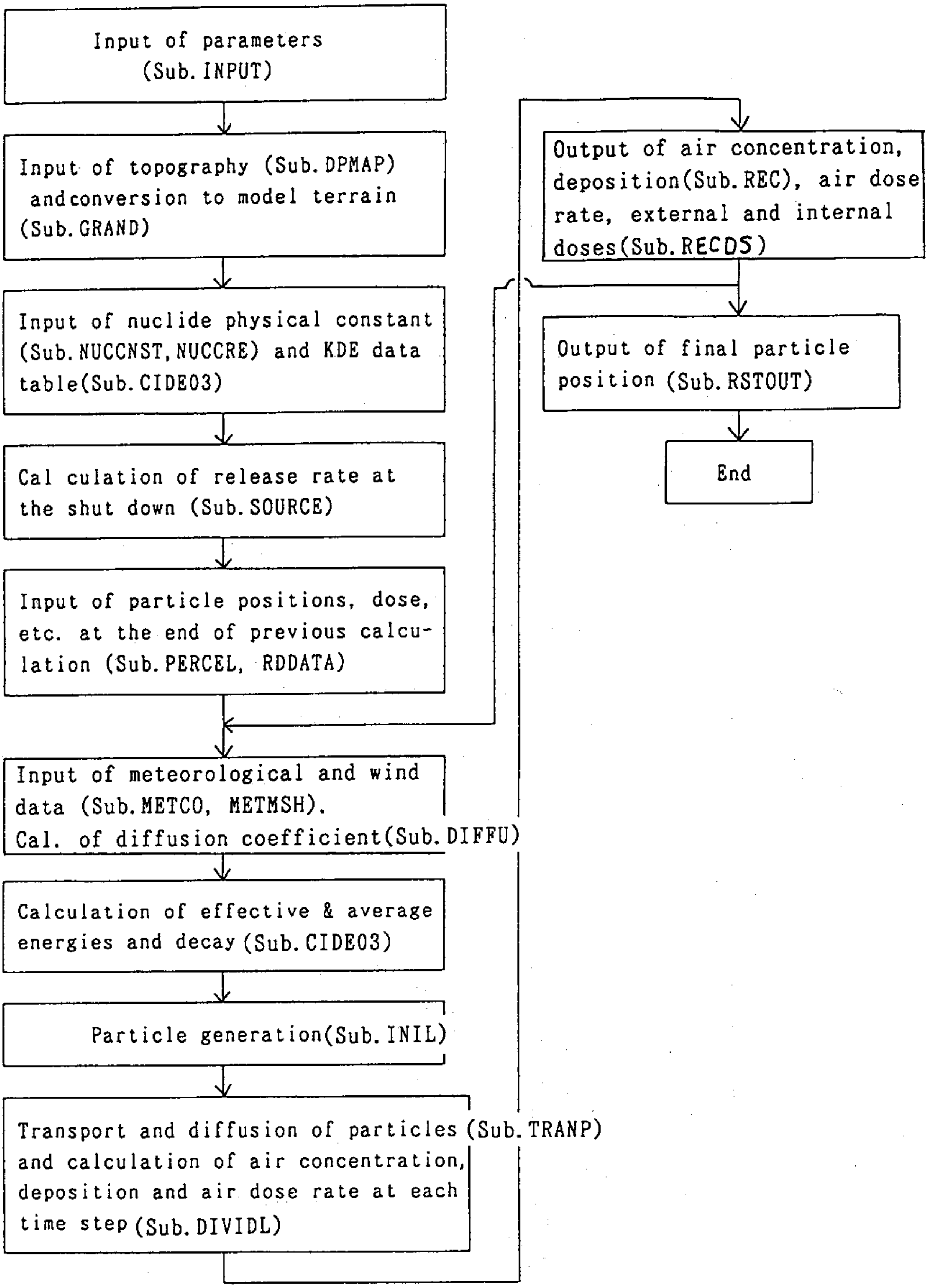


Fig. 3.3 Flow chart of concentration and dose calculation code.

```
MAIN  -----INPUT ----*INT
        I          +-*MOD
        I          +--TINTVL----*MOD
        I                     +--TCNVLN----*MOD
        +--GRAND -----DPMAP ----*FLOAT
        I          +-*INT
        I          +-*FLOAT
        I          +-*MIN
        I          +--GCNVX ----*TAN
        I          I          +-*SIN
        I          +--GCNVY ----*TAN
        I                     +-*COS
        I                     +-*SIN
        +--CIDE03-----NCCNST
        I          +--NUCCRE
        +--SOURCE-----TINTVL----*MOD
        I          I          +--TCNVLN----*MOD
        I          +-*EXP
        +-*FLOAT
        +-*INT
        +--DTTOS
        +--DATCHK----*MOD
        +--ISTODT----*INT
        +--PERCEL
        +--RDDATA-----DEPOSD-----TINTVL----*MOD
        I                     I          +--TCNVLN----*MOD
        I                     +-*EXP
        +--METCO ----*EXP
        I          +-*INT
        I          +--METMSH
        I          +--IBL
        I          +--LEVEL1----*SQRT
        I          +--PRISE ----*SQRT
        I                     +--ISTODT----*INT
        +-*SQRT
        +--CIDE  -----TINTVL----*MOD
        I          I          +--TCNVLN----*MOD
        I          +-*EXP
        I          +--DOSCNV----*ALOG
        I          +--XEINT ----*ALOG
        I                     +-*EXP
        +--INIL  ----*FLOAT
        I          +-*RANDOM
        I          +-*INT
        +--TRANP ----*SQRT
        I          +--DIFFU ----*FLOAT
        I                     +-*SQRT
        I                     +-*RANDOM
        I                     +-*INT
        +--DIVIDL----*INT
        I          +--GREF  ----*INT
        I          +-*ABS
        I          +-*SQRT
        I          +-*ALOG10
        +--PCKNG
        +--REC   ----*FLOAT
        +--RECDS -----EXDOSG-----XEINT ----*ALOG
        I          +--INDOSE             +-*EXP
        I          +--INTCNV
        I          +--FPDOSE
        +--RSTOUT
        +--XEXIT
```

Fig. 3.4 Tree structure of concentration and dose calculation code.

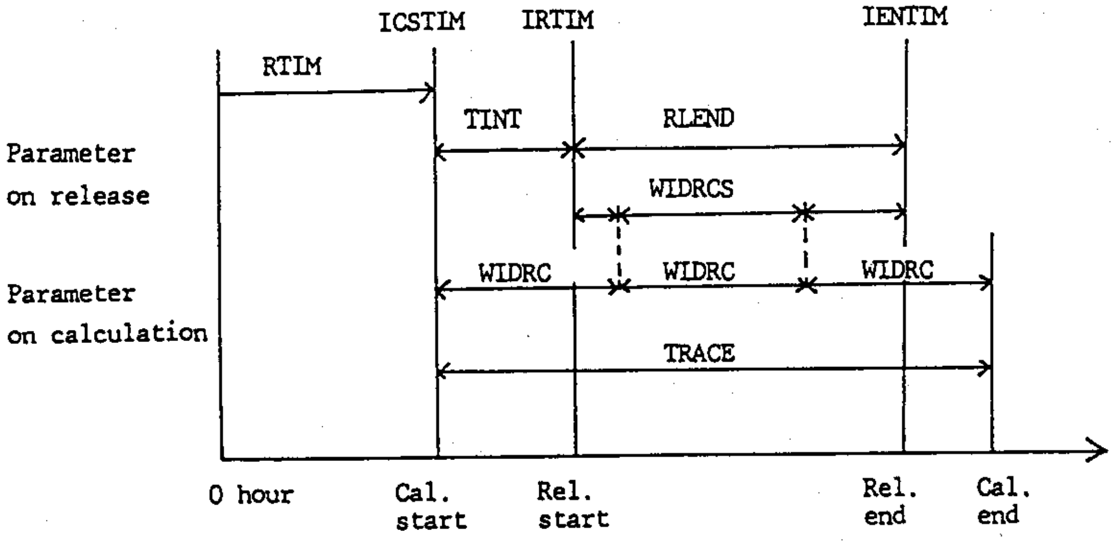


Fig. 3.5 Relation of time parameters.

```
&WIND04
NAMESP(1)='TESTSITE',
NAMESP(2)='        ',
ISTRDP=780823,
ISTRTP=160000,
ITINTP=10000,
IDMPIP=10000,
ICYCL=0,
&END
```

(a) Namelist for wind field model

```
&PRWDA
ASITE(1)='TESTSITE',
ASITE(2)='        ',
IRTIM(1)=780823,
IRTIM(2)=160000,
IENTIM(1)=780823,
IENTIM(2)=170000,
RLAT=35.7469,
RLONG=136.0203,
Z00=0.9000000E+02,
ICSTIM(1)=780823,
ICSTIM(2)=160000,
IWIDRC=10000,
ITRACE=10000,
ISDTIM(1)=780823,
ISDTIM(2)=150000,
REACT='BWR',
NCLID=2,
NAME(1)='NOBLE   ',
NAME(2)='IODINE  ',
RRATE(1)=3.7E+10,
RRATE(2)=3.7E+10,
&END
```

(b) Namelist of concentration and dose model.

Fig. 3.7 Example of namelist.

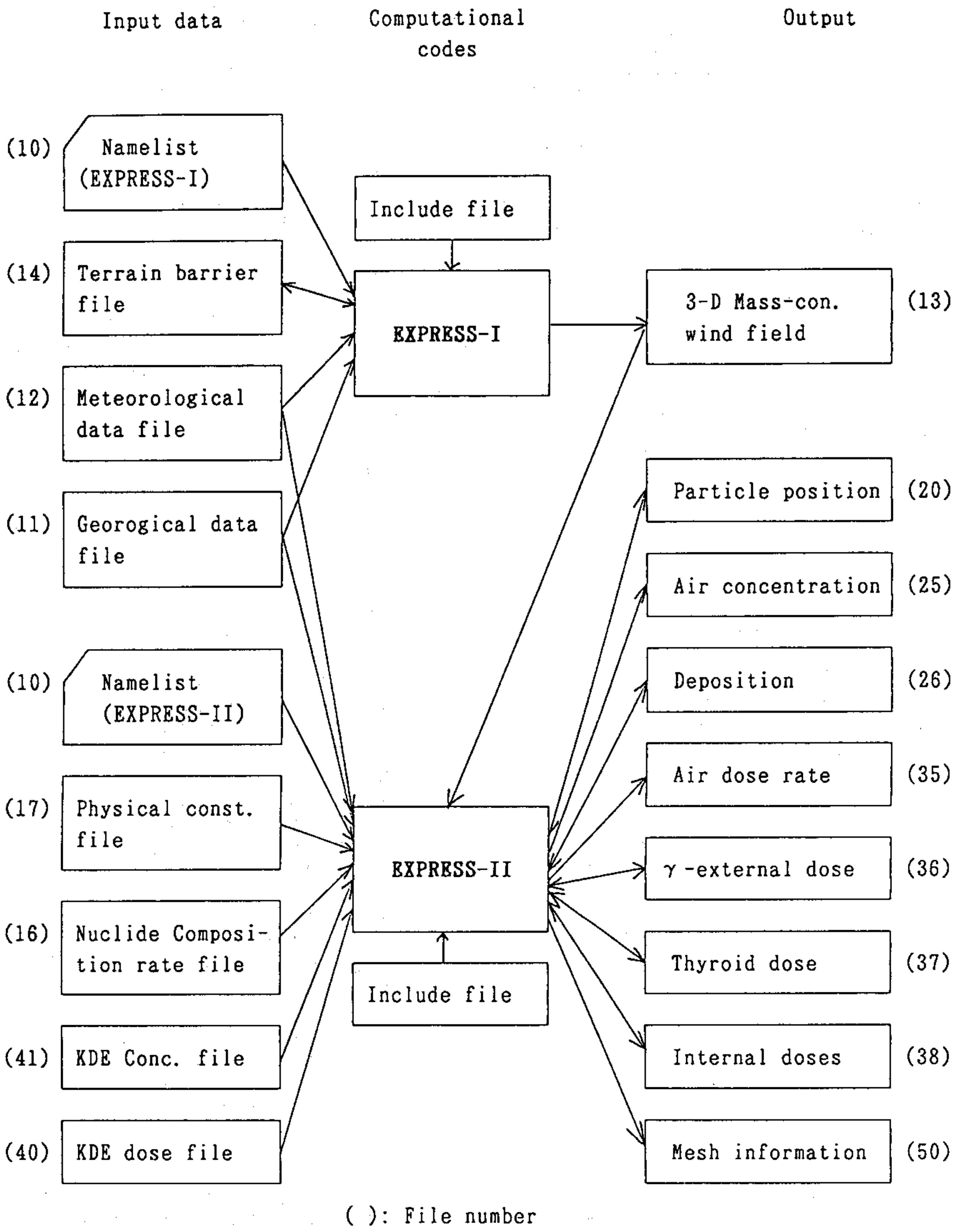


Fig. 3.6 Connection of codes, files and namelists.

```
ISNAME           SLT             SLG             RZLG             RZLT            ALLG            ALLT        NMLG  NMLT
  ↓               ↓               ↓               ↓                ↓               ↓               ↓           ↓     ↓
TESTMAP       0.3574666E+02  0.1360200E+03  -0.6000000E+01  -0.8000000E+01  0.1250000E+02  0.1250000E+02    51    51
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 25.4755096 55.5158081 91.0535278 114.390289 92.2414093 45.5401917 82.2290649 142.250031 111.3
 ↑   ↖
HT(1,1)  HT(2,1)
```

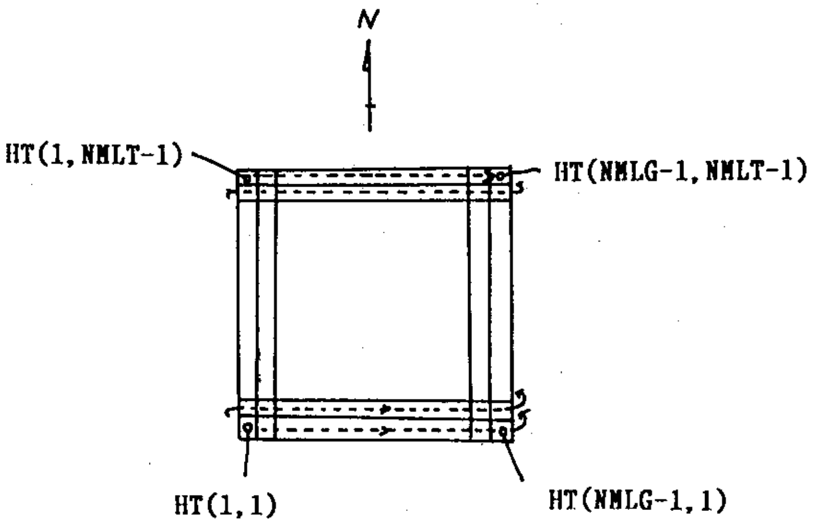
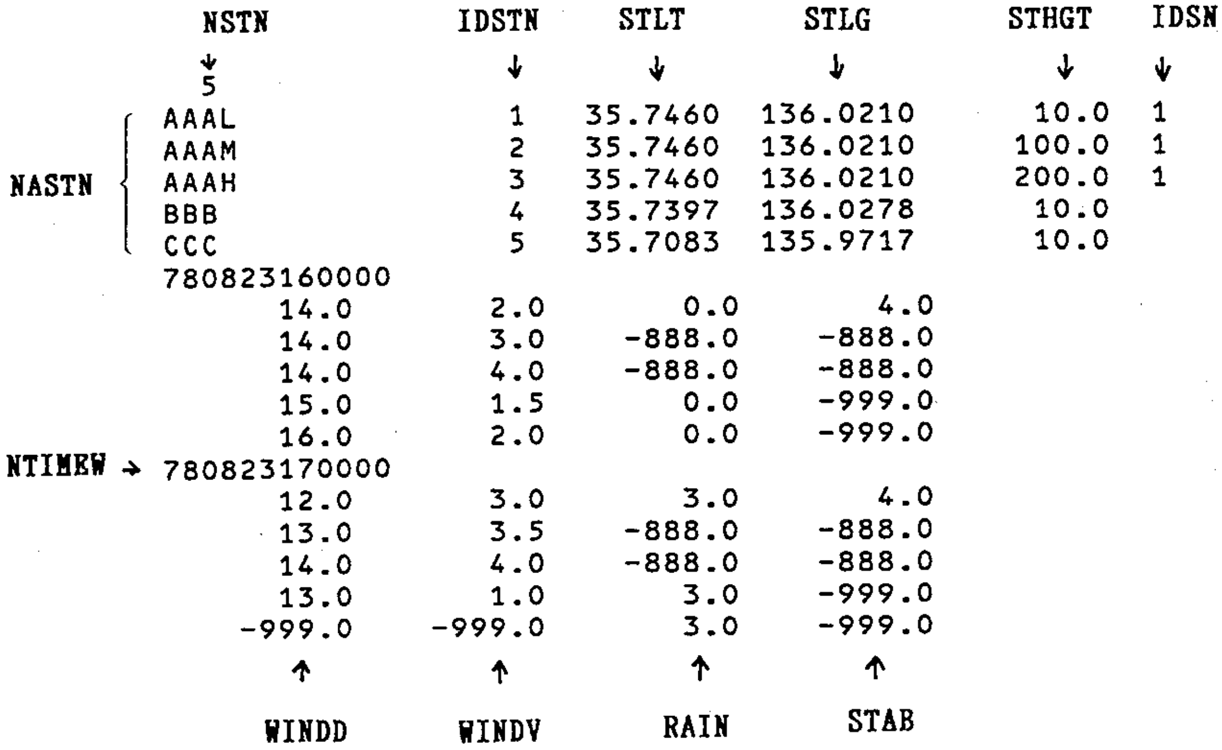


Fig. 3.8 Example of geological data file.



```
 5
AAAL           1  35.7460  136.0210     10.0  1
AAAM           2  35.7460  136.0210    100.0  1
AAAH           3  35.7460  136.0210    200.0  1
BBB            4  35.7397  136.0278     10.0
CCC            5  35.7083  135.9717     10.0
780823160000
      14.0     2.0      0.0      4.0
      14.0     3.0   -888.0   -888.0
      14.0     4.0   -888.0   -888.0
      15.0     1.5      0.0   -999.0
      16.0     2.0      0.0   -999.0
780823170000
      12.0     3.0      3.0      4.0
      13.0     3.5   -888.0   -888.0
      14.0     4.0   -888.0   -888.0
      13.0     1.0      3.0   -999.0
    -999.0  -999.0      3.0   -999.0
```

Fig. 3.9 Example of meteorological data file.

4. Concluding Remarks

This report described the computational codes EXPRESS-I, EXPRESS-IS and EXPRESS-II for the real-time simulation of atmospheric dispersion of radioactivities discharged into atmosphere due to nuclear accident.

The codes EXPRESS-I and -IS are developed for the estimation of 3-D wind fields around the site. Both codes employ the same numerical model, i.e., mass-consistent model. The difference of them is the CPU time of EXPRESS-IS is shorter than that of EXPRESS-I, although the required memory of EXPRESS-IS is larger than that of EXPRESS-I.

The code EXPRESS-II is developed for the estimation of air concentration, deposition, air dose rate, γ-external dose, thyroid dose and other internal doses. This code employs a particle random walk model. The CPU time and the required memory are reduced by the reduction of the number of particles. The statistical error due to the reduction of particles is minimized by the introduction of kernel density estimator.

The main specification of these codes are described in Appendices 6. These codes are originally developed by using main-frame computer FACOM M-380, Fujitsu Co., and already applied to VAX-computer and one engineering work station (A340 Σ, Fujitsu Co.) by the small changes of programs.

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Appendices 1 File Management for the Intermittent Uses

1) Access to the meteorological data

For the real-time operation, EXPRESS-I can search the meteorological data at the objective time from the file which piles up the sequential data by the routine work as shown in Fig. A1-1. The programs assume the meteorological data measured in the same time are grouped and the groups are arranged sequentially with time in the file. The program assumes that the number of a sequence of temporal data is 24, which is defined in Sub. DPWET1 (in EXPRESS-I) and METCO (in EXPRESS-II) by data statement NHOR.

Figure A1-1 shows the access of two programs to the files in the case of the calculation starting time 11:00, the calculation period 2:00 and the dump interval 1:00. Although the time index of diagnostic wind field is 11:00 and 12:00, those of concentration and doses are 12:00 and 13:00. It is because EXPRESS-II predicts the concentration and doses after 1 hour based on the assumption of temporally constant wind field during 1 hour. In the case where there is no time index in the file corresponding to the calculation starting time or dump interval, the program will stop with error message. Thus, even when the release starting time is 11:20, the calculation starting time should be set to 11:00.

2) Input/output of files for intermittent uses

Fig. A1-2 shows the calculations which are carried out intermittently after every input of hourly meteorological data. The temporal situation is the same as Fig. A1-1. The output of particle positions at 12:00 is used in the calculation from 12:00 as an initial condition of distribution of radioactivity discharged during the period from 11:00 to 12:00. The output of deposition, γ-external dose, thyroid dose and other internal doses at 12:00 is input to the calculation from 12:00 for the accumulation of these values.

In the case of intermittent uses, new calculated results of wind fields are overwritten on old data in the file and those of concentration and doses are written additionally after the last data in the file.

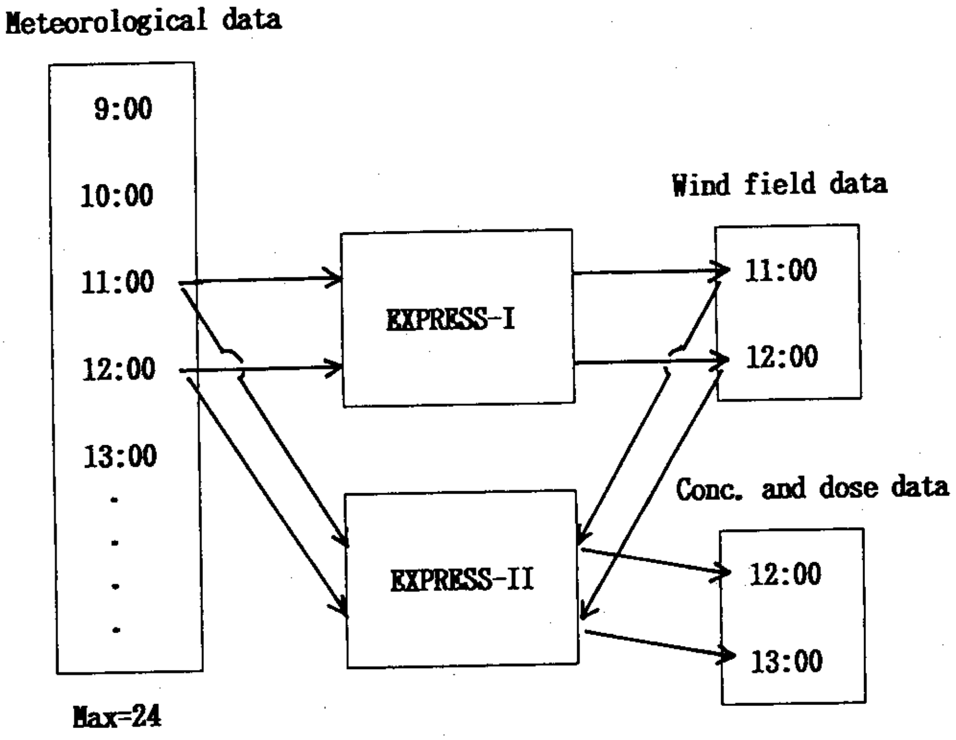


Fig. A1-1 Example of time control in the files.

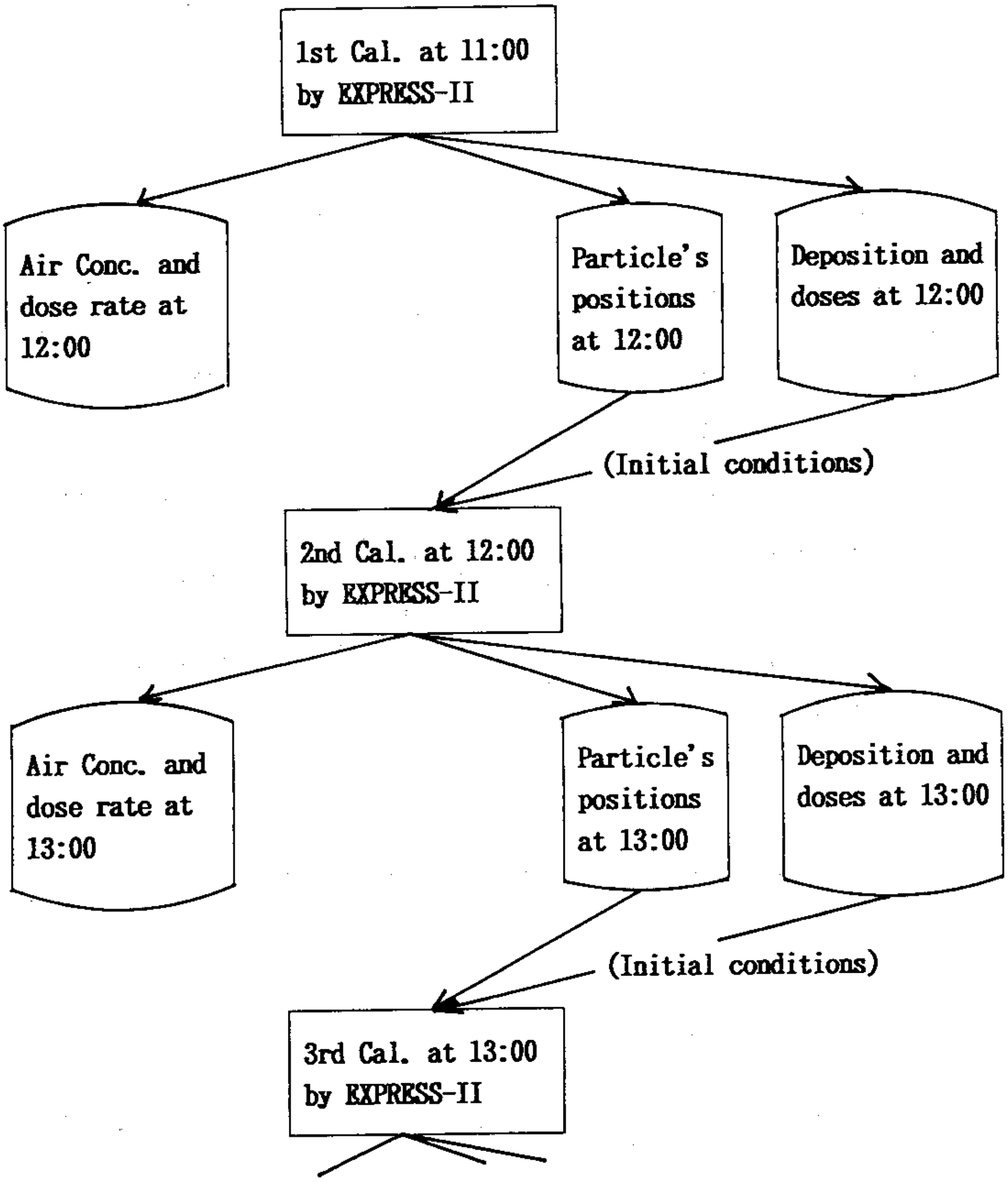


Fig. A1-2 Example of intermitted use for real-time simulation.

Appendices 2 EXPRESS-IS: Modified Version of EXPRESS-I

In the program of EXPRESS-I, the weighted interpolation is carried out after the exclusion of the data-lack observatories at every input of meteorological data. It means that three observatories which have heavy weights for the objective grid point must be decided at the every input of meteorological data. However, if the observatories and computational grids are fixed and the lacks of data never appear, the observatories which are used for the interpolation and their weight values to the objective grid are always constant. It is because the selection of three observatories which have heavy weights and calculation of their weight values are based on only geometric relation between the observatories and the objective grids.

Thus, EXPRESS-IS input the three heavy-weight observatories and their weights for 3-D grids from the file instead of calculation of them so that it can reduce the CPU time, comparing with EXPRESS-I. The file which contains data of three heavy-weight observatories and their weights is made in the first application of EXPRESS-IS to the objective region and, from the second application, the data in the file is used as input data. When EXPRESS-IS finds the lacks of data from several stations, it firstly estimates the wind vectors at these observatories based on Eq.(2) to (7) and secondary interpolates the winds onto 3-D grids. The difference of the interpolation flow between EXPRESS-I and -IS is shown in Fig. A2-1. In EXPRESS-IS, the selection of three observatories and the calculation of the weights are omitted and the interpolation of winds at the data-lack observatories is added. In the program of EXPRESS-IS, the interpolation of winds at the data-lack observatories is performed in Sub. WIND01 and the interpolation of winds to 3-D grids in Sub. WEIT3D.

Input data for EXPRESS-IS are completely the same as those of EXPRESS-I. However, ICYCL in the namelist means the flag to decide whether three observatories and their weights are calculated or input. And the barrier file of EXPRESS-I is allotted to the weight file. The file format of weight file is as follows.

Weight file

Input subroutine: WEIT3D (EXPRESS-IS)

NEARS(I,J,K,K,IXY)	VBS	sequential numbers of three observatories which have heavy weights to the grid(I,J,K).
WEIGHT(I,J,K,L,IXY)	VBS	weights of three observatories to the grid (I,J,K).

(I,J,K) is mesh number, L is index of three observatories, IXY=1 means the weight for x-component and IXY=2 means for y-component.

The tree structure, the list of common statements in mail program and subroutines and the classification of Fortran statement are shown in Fig. A2-2, Table A2-1 and Table A2-2, respectively.

Table A2-1 Subprogram name vs. Common block name in EXPRESS-IS.

```
              ==== SUBPROGRAM NAME  VS.  COMMON BLOCK NAME ====
+--------------+------------------+
I**************IDDDGG.MNPPR.RTWWW.I
I**************IPPPCC.AACWE.EOEII.I
I**************IMWWNN.IMRWL.LPINN.I
I**************IAEIVV.NE1IU.UOTDD.I
I**************IPTNXY. L NX.XO3AO.I
I**************I 1D  .   D .2 DD1.I
+--------------+------------------+
I   1./BARIA / I     . X   .  X X.I
I   2./BL1   / IX X  .XXX X.XXXXX.I
I   3./BL1D  / I  X  .X X X.X  XX.I
I   4./DIVDT / I     .  X X.X    .I
I   5./DPCOMM/ IXXX  .XX   .     .I
I..............I..................I
I   6./EPSZ  / I     .  X  .X    .I
I   7./GDATA / IX X  .     .     .I
I   8./MAPDT / IX XXX.X    . XX X.I
I   9./MDFLG / I X   .     .  X X.I
I  10./MTNAME/ I X   .     .  X X.I
I..............I..................I
I  11./STDATA/ I X   .X    .  X X.I
I  12./STG   / I     .     .  X X.I
I  13./STNAM / I  X  . X   .     .I
I  14./SYSPIO/ I     .     .    X.I
I  15./TCONTP/ I     .XX   .     .I
I..............I..................I
I  16./WINDDT/ I X   .X    .  X X.I
I  17./WINDOB/ I X   .XX   .    X.I
I  18./WORK  / I     .  X  .X    .I
I  19./W3D   / I     .     .  X X.I
+--------------+------------------+
```

Table A2-2 Classification of Fortran statements of EXPRESS-IS.

```
=====================================================================================================
I        T H E   C L A S S I F I C A T I O N   O F   F O R T R A N   S T A T E M E N T S            I
=====================================================================================================
I   COMMENT              469( 26.71 %)                  X     WAIT                  0(  0.0  %)      I
I   CONTINUATION         213( 12.13 %)                  X     INQUIRE               0(  0.0  %)      I
I   ASSIGNMENT           418( 23.80 %)                  X     COMPLEX               0(  0.0  %)      I
I   ASSIGN                 0(  0.0  %)                  X     LOGICAL               0(  0.0  %)      I
I   GO TO                  4(  0.23 %)                  X     INTEGER               0(  0.0  %)      I
I   ASSIGNED GO TO         0(  0.0  %)                  X     CHARACTER             9(  0.51 %)      I
I   COMPUTED GO TO         0(  0.0  %)                  X     DOUBLE PRECISION      0(  0.0  %)      I
I   ARITHMETIC IF          0(  0.0  %)                  X     REAL                 15(  0.85 %)      I
I   LOGICAL IF           127(  7.23 %)                  X     EQUIVALENCE           0(  0.0  %)      I
I        ASSIGNMENT          88    PRINT            O   X     DATA                 12(  0.68 %)      I
I        ASSIGN               0    PUNCH            O   X     NAMELIST              1(  0.06 %)      I
I        GO TO               39    REWIND           O   X     IMPLICIT              0(  0.0  %)      I
I        ASSIGNED GO TO       0    FIND             O   X     PARAMETER            22(  1.25 %)      I
I        COMPUTED GO TO       0    WAIT             O   X     COMMON               45(  2.56 %)      I
I        ARITHMETIC IF        0    CALL             O   X     SAVE                  0(  0.0  %)      I
I        OPEN                 0    RETURN           O   X     DIMENSION             4(  0.23 %)      I
I        CLOSE                0    STOP             O   X     EXTERNAL              0(  0.0  %)      I
I        READ                 0    PAUSE            O   X     INTRINSIC             0(  0.0  %)      I
I        WRITE                0    DECODE           O   X     DEFINE FILE           0(  0.0  %)      I
I        BACKSPACE            0    ENCODE           O   X     PROGRAM               0(  0.0  %)      I
I        ENDFILE              0    INQUIRE          O   X     BLOCKDATA             0(  0.0  %)      I
I   IF (...) THEN         34(  1.94 %)                  X     FUNCTION              3(  0.17 %)      I
I   DO                   109(  6.21 %)                  X     SUBROUTINE           11(  0.63 %)      I
I   DO   UNTIL(...)        0(  0.0  %)                  X     ENTRY                 0(  0.0  %)      I
I   DO   WHILE(...)        0(  0.0  %)                  X     CALL                 10(  0.57 %)      I
I   ELSE                  19(  1.08 %)                  X     RETURN               15(  0.85 %)      I
I   ELSE IF                0(  0.0  %)                  X     STOP                  4(  0.23 %)      I
I   END IF                34(  1.94 %)                  X     PAUSE                 0(  0.0  %)      I
I   FORMAT                26(  1.48 %)                  X     END                  15(  0.85 %)      I
I   OPEN                   0(  0.0  %)                  X     CONTINUE             85(  4.84 %)      I
I   CLOSE                  0(  0.0  %)                  X     DECODE                0(  0.0  %)      I
I   READ                  14(  0.80 %)                  X     ENCODE                0(  0.0  %)      I
I   WRITE                 38(  2.16 %)                  X     DEBUG                 0(  0.0  %)      I
I   BACKSPACE              0(  0.0  %)                  X     AT                    0(  0.0  %)      I
I   ENDFILE                0(  0.0  %)                  X     DISPLAY               0(  0.0  %)      I
I   PRINT                  0(  0.0  %)                  X     INIT                  0(  0.0  %)      I
I   PUNCH                  0(  0.0  %)                  X     TRACE                 0(  0.0  %)      I
I   REWIND                 0(  0.0  %)                  X     -- ROGUE --           0(  0.0  %)      I
I   FIND                   0(  0.0  %)                  X     NCHARACTER (JEF)      0(  0.0  %)      I
=====================================================================================================

                               TOTAL STATEMENTS =  1756
```

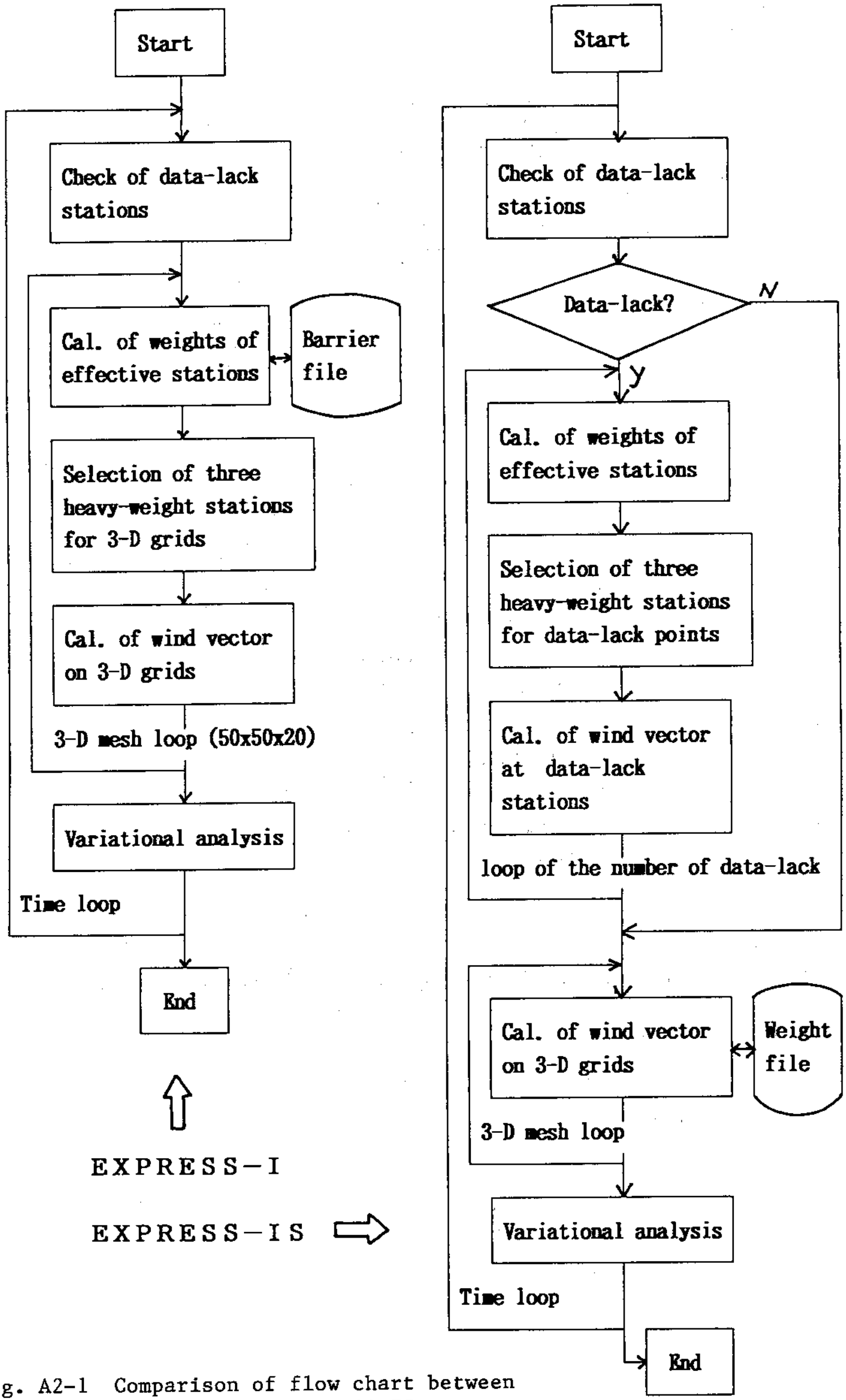


Fig. A2-1 Comparison of flow chart between EXPRESS-I and EXPRESS-IS.

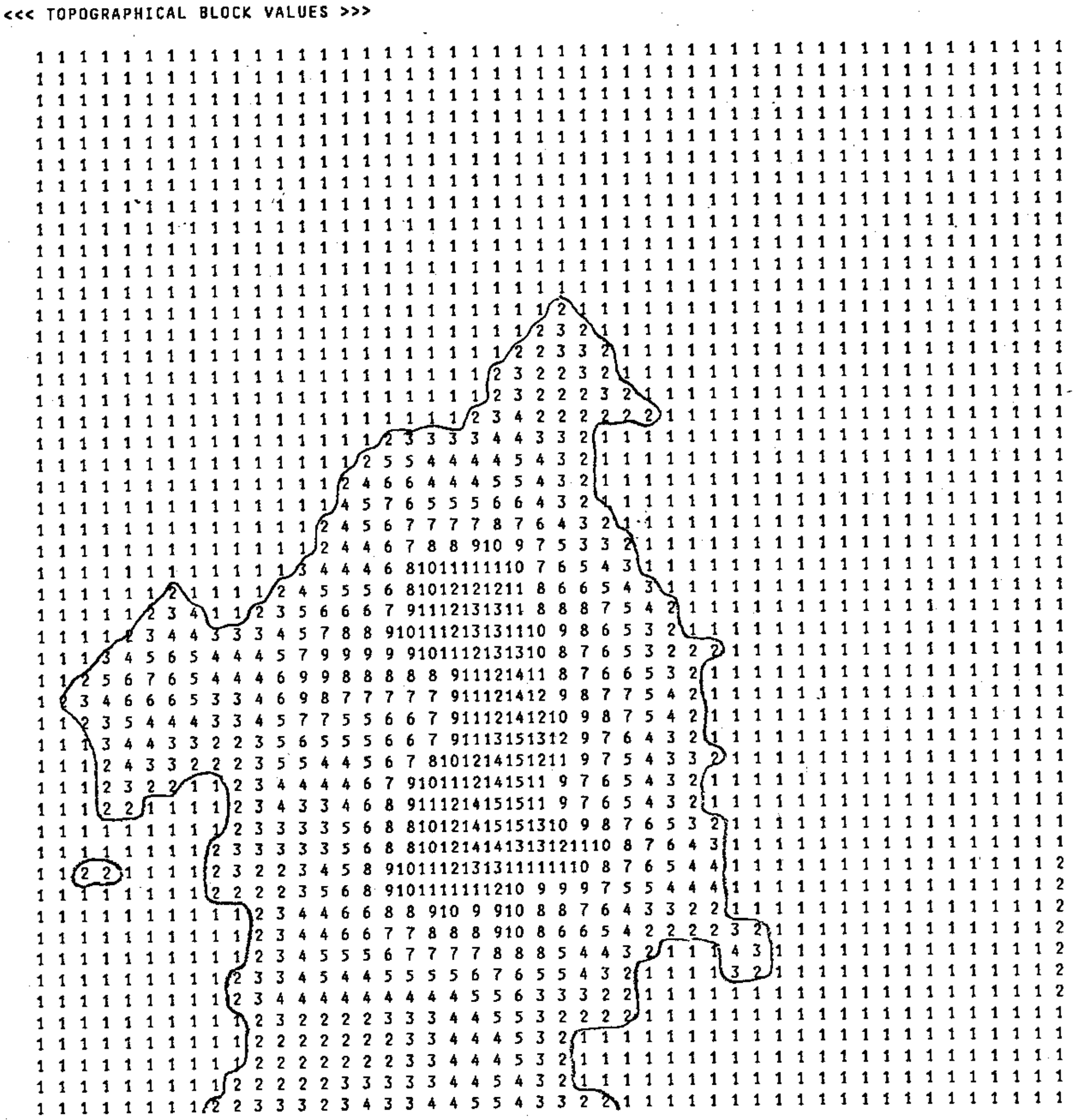
```
MAIN  -----NAMEL ----*MOD
        +--DPMAP ----*FLOAT
        +--TOPOO ----*INT
        I          +-*MIN
        +--DPWET1----*INT
        +--WINDO1----*COS
        I          +-*SIN
        I          +--GCNVX ----*TAN
        I          I          +-*SIN
        I          +--GCNVY ----*TAN
        I          I          +-*COS
        I          I          +-*SIN
        I          +-*INT
        I          +-*ABS
        I          +-*ALOG10
        I          +-*EXP
        I          +--PWWIND
        I          +--WEIT3D----*FLOAT
        I          I          +-*ABS
        I          I          +-*INT
        I          I          +-*MAX0
        I          I          +-*ALOG10
        I          I          +-*EXP
        I          +-*MAX0
        +--RELUX2----*DBLE
        I          +-*MOD
        I          +--PCR1
        +--WINDAD----*MAX0
        I          +-*MOD
        I          +-*MIN0
        +--DPWIND----*FLOAT
        +-*MOD
```

Fig. A2-2 Tree structure of EXPRESS-IS.

Appendices 3 Sample Output

(1) EXPRESS-I

```
&WINDO4
KMAX=21,DZ=50.0000000,ICYCL=0,NAMESP='TESTSITE','          ',ISTRDP=780823,ISTRTP=160000,ITINTP=10000,
&END

  **********************
  ***** INPUT DATA *****
  **********************

    SITE NAME  =TESTSITE

    START DATE = 780823 YYMMDD

    START TIME = 160000 HHMMSS

    CAL. PERIOD=  10000 HHMMSS

    DUMP INTVL =  10000 HHMMSS

 ***** TOPOGRAPHICAL DATA *****

    ORIGIN LATITUDE=  35.7467 DEG    LONGITUDE= 136.0200 DEG

    LOWER LEFT CORNER      (  -5875.0,  -7875.0) M

    MESH WINDTH      DELX=  250.0 M        DELY=  250.0 M        DELZ=   50.0 M

    MESH NUMBER      IMAX=  50             JMAX=  50             KMAX=  21

    MINIMUM HEIGHT=    0.0 M
```



```
<<< TOPOGRAPHICAL BLOCK VALUES >>>

 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 3 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 2 2 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 2 2 2 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 4 2 2 2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 3 3 3 4 4 3 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 5 5 4 4 4 4 5 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 4 6 6 4 4 4 5 5 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 4 5 7 6 5 5 5 6 6 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 2 4 5 6 7 7 7 7 8 7 6 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 2 4 4 6 7 8 8 910 9 7 5 3 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 3 4 4 4 6 81011111110 7 6 5 4 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 2 1 1 1 1 2 4 5 5 5 6 81012121211 8 6 6 5 4 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 2 3 4 1 1 2 3 5 6 6 6 7 91112131311 8 8 8 7 5 4 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 2 3 4 4 3 3 3 4 5 7 8 8 910111213131110 9 8 6 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 3 4 5 6 5 4 4 4 5 7 9 9 9 9 9101112131310 8 7 6 5 3 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 2 5 6 7 6 5 4 4 4 6 9 9 8 8 8 8 8 911121411 8 7 6 6 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 2 3 4 6 6 6 5 3 3 4 6 9 8 7 7 7 7 7 911121412 9 8 7 7 5 4 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 2 3 5 4 4 4 3 3 4 5 7 7 5 5 6 6 7 91112141210 9 8 7 5 4 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 3 4 4 3 3 2 2 3 5 6 5 5 5 6 6 7 91113151312 9 7 6 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 2 4 3 3 2 2 2 3 5 5 4 4 5 6 7 8101214151211 9 7 5 4 3 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 2 3 2 2 1 1 2 3 4 4 4 4 6 7 9101112141511 9 7 6 5 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 2 2 1 1 1 1 2 3 4 3 3 4 6 8 9111214151511 9 7 6 5 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 2 3 3 3 3 5 6 8 810121415151310 9 8 7 6 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 2 3 3 3 3 3 5 6 8 8101214141313121110 8 7 6 4 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 2 2 1 1 1 1 2 3 2 2 3 4 5 8 9101112131311111110 8 7 6 5 4 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
 1 1 1 1 1 1 1 1 2 2 2 2 3 5 6 8 9101111111210 9 9 9 7 5 5 4 4 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
 1 1 1 1 1 1 1 1 1 1 2 3 4 4 6 6 8 8 910 9 910 8 8 7 6 4 3 3 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
 1 1 1 1 1 1 1 1 1 1 2 3 4 4 6 6 7 7 8 8 8 910 8 6 6 5 4 2 2 2 2 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 2
 1 1 1 1 1 1 1 1 1 1 2 3 4 5 5 5 6 7 7 7 7 8 8 8 5 4 4 3 2 1 1 1 4 3 1 1 1 1 1 1 1 1 1 1 1 1 1 2
 1 1 1 1 1 1 1 1 1 2 3 3 4 5 4 4 5 5 5 5 6 7 6 5 5 4 3 2 1 1 1 1 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 2
 1 1 1 1 1 1 1 1 1 2 3 4 4 4 4 4 4 4 4 4 5 5 6 3 3 3 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
 1 1 1 1 1 1 1 1 1 1 2 3 2 2 2 2 3 3 3 4 4 5 5 3 2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 3 3 4 4 4 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 3 3 4 4 4 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3 4 4 5 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 2 2 3 3 3 2 3 4 3 3 4 4 5 5 4 3 3 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

This figure shows the block topography. The array of data is 50×50. The upward is corresponding to the north. The number (N) means the cell number on the ground and the terrain height in the model is calculated by multiplying N-1 by vertical cell size. This example indicates the peninsula which has mountain (about 700 m) in the center.

```
**** METEOROLOGICAL DATA *****

 *ATMOSPHERIC STABILITY =  4

               ALPHA1  = 0.500

               ALPHA2  = 1.000
```

α_1/α_2 in Eq.(14)

```
*OBSERVED WIND DATA

 OBSERVATORY NAME          X(M)        Y(M)        Z-G        Z-BOT        US          VS        I
1AAAL                   89.4952    -72.8989    10.0000    110.0000     1.4142     -1.4142
2AAAM                   89.4952    -72.8989   100.0000    200.0000     2.1213     -2.1213
3AAAH                   89.4952    -72.8989   200.0000    300.0000     2.8284     -2.8284
4BBB                   703.6257   -771.5129    10.0000     10.0000     0.5740     -1.3858
5CCC                 -4361.1680  -4258.5078    10.0000     10.0000     0.0000     -2.0000

***** INTERPORATED WIND ON DIAGONAL LINE *****
       1  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 11   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 11   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 21   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 21   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 31   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 31   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 41   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 41   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
      11  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
      11  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
      11 11   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.2   1.0   2.5   3.2   3.3   3.4   3.5   3.
      11 11   0.0  -3.3  -3.8  -4.1  -4.4  -4.6  -4.8  -4.8  -4.5  -3.6  -3.3  -3.3  -3.4  -3.5  -3.
      11 21   0.0   0.0   0.0   1.4   2.4   2.7   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      11 21   0.0   0.0   0.0  -3.5  -2.9  -2.8  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      11 31   1.4   1.6   1.8   2.0   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      11 31  -1.6  -1.7  -1.8  -2.0  -2.4  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      11 41   1.4   1.4   1.7   2.2   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      11 41  -1.6  -1.5  -1.8  -2.2  -2.4  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      21  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
      21  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
      21 11   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.3   3.3   3.4   3.5   3.
      21 11   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0  -3.3  -3.3  -3.4  -3.5  -3.
      21 21   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.3   3.3   3.4   3.5   3.
      21 21   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0  -3.3  -3.3  -3.4  -3.5  -3.
      21 31   0.0   0.0   0.0   1.9   2.4   2.5   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      21 31   0.0   0.0   0.0  -1.9  -2.4  -2.5  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      21 41   0.9   1.3   1.7   1.9   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      21 41  -1.4  -1.6  -1.8  -2.0  -2.4  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      31  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
      31  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
      31 11   0.0   0.0   0.0   2.5   2.6   2.7   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      31 11   0.0   0.0   0.0  -2.4  -2.5  -2.7  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      31 21   0.0   0.0   1.6   1.9   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      31 21   0.0  -2.0  -1.8  -2.0  -2.4  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      31 31   0.8   1.2   1.6   1.8   2.4   2.5   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      31 31  -1.6  -1.9  -2.0  -2.0  -2.4  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      31 41   0.8   1.2   1.6   1.9   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      31 41  -1.6  -1.8  -1.9  -2.0  -2.4  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      41  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
      41  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
      41 11   0.8   1.1   1.7   2.1   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      41 11  -1.7  -2.2  -2.4  -2.4  -2.5  -2.7  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      41 21   0.8   1.1   1.6   2.0   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      41 21  -1.7  -2.0  -2.2  -2.3  -2.5  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      41 31   0.8   1.1   1.4   1.8   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      41 31  -1.7  -2.0  -2.1  -2.1  -2.5  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
      41 41   0.8   1.2   1.6   2.1   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
      41 41  -1.6  -1.9  -1.9  -2.2  -2.5  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.

 ***** ADJUSTED WIND ON EVERY 10 GRID *****
       1  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 11   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 11   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 21   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 21   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 31   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
       1 31   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
```

```
 1 41   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
 1 41   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
11  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
11  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
11 11   0.0  -0.5  -0.2  -0.1  -0.0   0.0   0.1   0.3   1.1   2.6   3.2   3.4   3.4   3.5   3.
11 11   0.0  -3.2  -3.7  -4.0  -4.3  -4.6  -4.7  -4.8  -4.4  -3.6  -3.3  -3.4  -3.4  -3.5  -3.
11 21   0.0   0.0   0.0   0.4   1.3   1.8   2.1   2.3   2.6   2.8   2.9   3.1   3.2   3.3   3.
11 21   0.0   0.0   0.0  -5.0  -4.3  -4.0  -3.9  -3.9  -3.9  -3.8  -3.8  -3.8  -3.8  -3.8  -3.
11 31   1.1   1.3   1.5   1.7   2.2   2.3   2.7   2.8   2.9   3.0   3.1   3.2   3.3   3.4   3.
11 31  -1.3  -1.5  -1.6  -1.8  -2.2  -2.4  -2.7  -2.8  -2.9  -3.0  -3.1  -3.2  -3.3  -3.4  -3.
11 41   1.3   1.3   1.7   2.1   2.4   2.5   2.8   3.0   3.1   3.1   3.2   3.3   3.4   3.4   3.
11 41  -1.4  -1.4  -1.7  -2.1  -2.4  -2.5  -2.8  -2.9  -3.0  -3.1  -3.2  -3.3  -3.4  -3.4  -3.
21  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
21  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
21 11   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   4.0   4.6   4.5   4.3   4.
21 11   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0  -4.3  -3.7  -3.8  -3.8  -3.
21 21   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   3.2   3.3   3.4   3.5   3.
21 21   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0  -2.1  -2.4  -2.7  -2.9  -3.
21 31   0.0   0.0   0.0   1.8   2.3   2.6   3.0   3.1   3.2   3.3   3.4   3.5   3.5   3.6   3.
21 31   0.0   0.0   0.0  -0.9  -1.5  -1.9  -2.3  -2.5  -2.6  -2.8  -2.9  -3.1  -3.2  -3.3  -3.
21 41   0.9   1.4   1.7   1.9   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
21 41  -1.3  -1.5  -1.7  -1.8  -2.3  -2.5  -2.8  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.
31  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
31  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
31 11   0.0   0.0   0.0   0.8   1.2   1.6   1.9   2.1   2.3   2.5   2.7   2.9   3.0   3.1   3.
31 11   0.0   0.0   0.0  -2.7  -2.6  -2.7  -2.8  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.
31 21   0.0   0.0   1.4   1.4   1.9   2.1   2.5   2.6   2.8   2.9   3.0   3.1   3.2   3.3   3.
31 21   0.0  -2.5  -2.3  -2.4  -2.8  -2.9  -3.2  -3.3  -3.3  -3.4  -3.4  -3.5  -3.5  -3.6  -3.
31 31   0.7   1.1   1.5   1.8   2.3   2.5   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
31 31  -1.7  -1.9  -2.0  -2.1  -2.5  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.4  -3.4  -3.5  -3.
31 41   0.9   1.3   1.7   1.9   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
31 41  -1.6  -1.8  -1.9  -2.0  -2.4  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
41  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
41  1   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.0   0.
41 11   0.8   1.1   1.6   2.0   2.4   2.6   2.8   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.
41 11  -1.6  -2.1  -2.4  -2.3  -2.5  -2.6  -2.9  -3.0  -3.1  -3.1  -3.2  -3.3  -3.4  -3.5  -3.
41 21   0.7   1.0   1.5   1.9   2.3   2.5   2.8   2.9   3.0   3.1   3.2   3.3   3.4   3.4   3.
41 21  -1.7  -2.0  -2.2  -2.3  -2.5  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
41 31   0.8   1.2   1.4   1.8   2.4   2.6   2.9   3.0   3.1   3.2   3.2   3.3   3.4   3.5   3.
41 31  -1.7  -2.0  -2.1  -2.1  -2.5  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.
41 41   0.8   1.2   1.6   2.0   2.4   2.6   2.9   3.0   3.1   3.2   3.3   3.3   3.4   3.5   3.
41 41  -1.6  -1.9  -2.0  -2.3  -2.5  -2.6  -2.9  -3.0  -3.1  -3.2  -3.3  -3.3  -3.4  -3.5  -3.


                 *******************************************************
                 *                                                     *
                 *                    NORMAL END                       *
                 *                                                     *
                 *******************************************************
```

→U−component(upper) and V−component(lower) at the grid (31,31).

KZ = 1.....KMAX from the left to the right.

(2) EXPRESS-II

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    ******************
    *** INPUT DATA ***
    ******************

 ******* RELEASE INFORMATION *************

         ACCIDENT SITE : TESTSITE

                   ( LATITUDE= 35.7469 DEG    LONGITUDE= 136.0203 DEG    REL HEIGHT=  90.0 M    TERR

         RELEASED DATE  = 780823 YMD

         RELEASED TIME  = 160000 HMS

         REL. END DATE  = 780823 YMD

         REL. END TIME  = 170000 HMS

         SHUT DOWN DAY  =  780823 YMD

         SHUT DOWN TIME =  150000 HMS

         REACTOR TYPE   =  BWR

         BURN UP        = 10000.0MWD/UT

         INIL STANDARD DEV. HORI=   0.0     VERT=   0.0 M

         PARTICLE NUM.(MAXP) = 1000


 ******* TIME INFORMATION *******

         METEOR. DATA INPUT INTERVAL (S) =3600.0

         SOURCE DATA INPUT INTERVAL  (S) =3600.0

         RESULT OUTPUT INTERVAL      (S) =3600.0

         CAL. STARTING DAY   (YMD) =  780823

         CAL. STARTING TIME  (HMS) =  160000

         TRACING TIME INTERVAL (S) =  3600.0

         RELEASE PERIOD OF MAXP(S) =  7200.0

         INITIAL TIME STEP     (S) =    30.0


****** MESH INFORMATION(FROM MAP FILE) *******

  <MET. MESH>

MINIMUM P(X,Y) -5500.0 -7500.0 M   MESH WIDTH(X,Y,Z)  250.0  250.0   50.0 M   MESH NUMBER(X,Y,Z)
```

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******* TERRAIN HEIGHT INFORMATION *******

         MODEL TERRAIN BLOCK(WINDFIELD MESH)

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
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1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 3 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 2 2 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 2 2 2 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 4 2 2 2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 3 3 3 4 4 3 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 2 5 5 4 4 4 4 5 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 2 4 6 6 4 4 4 5 5 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 4 5 7 6 5 5 5 6 6 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 2 4 5 6 7 7 7 7 8 7 6 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 2 4 4 6 7 8 8 910 9 7 5 3 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 3 4 4 4 6 810111111110 7 6 5 4 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 2 1 1 1 1 2 4 5 5 5 6 81012121211 8 6 6 5 4 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 2 3 4 1 1 2 3 5 6 6 6 7 91112131311 8 8 8 7 5 4 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 2 3 4 4 3 3 3 4 5 7 8 8 910111213131110 9 8 6 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 3 4 5 6 5 4 4 4 5 7 9 9 9 9101112131310 8 7 6 5 3 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 5 6 7 6 5 4 4 4 6 9 9 8 8 8 8 8 911121411 8 7 6 6 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 4 6 6 6 5 3 3 4 6 9 8 7 7 7 7 7 911121412 9 8 7 7 5 4 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 3 5 4 4 4 3 3 4 5 7 7 5 5 6 6 7 91112141210 9 8 7 5 4 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 3 4 4 3 3 2 2 3 5 6 5 5 5 6 6 7 91113151312 9 7 6 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 2 4 3 3 2 2 2 3 5 5 4 4 5 6 7 8101214151211 9 7 5 4 3 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 2 3 2 2 1 1 2 3 4 4 4 4 6 7 9101112141511 9 7 6 5 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 2 2 1 1 1 1 2 3 4 3 3 4 6 8 9111214151511 9 7 6 5 4 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 2 3 3 3 3 5 6 8 810121415151310 9 8 7 6 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 2 3 3 3 3 3 5 6 8 8101214141313121110 8 7 6 4 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 2 1 1 1 1 2 3 2 2 3 4 5 8 9101112131311111110 8 7 6 5 4 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 2 2 2 2 3 5 6 8 9101111111210 9 9 9 7 5 5 4 4 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 2 3 4 4 6 6 8 8 910 9 910 8 8 7 6 4 3 3 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 2 3 4 4 6 6 7 7 8 8 8 910 8 6 6 5 4 2 2 2 2 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 2 3 4 5 5 5 6 7 7 7 7 8 8 8 5 4 4 3 2 1 1 1 4 3 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 2 3 3 4 5 4 4 5 5 5 5 6 7 6 5 5 4 3 2 1 1 1 1 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 2 3 4 4 4 4 4 4 4 4 4 5 5 6 3 3 3 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 2 3 2 2 2 2 3 3 3 4 4 5 5 3 2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 3 3 4 4 4 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 3 3 4 4 4 5 3 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1




*** RELEASE POINT ****

 X00=    26.2 M    Y00=    30.4 M    Z00=    90.0 M
```

```
******* SOURCE INFORMATION ********

        NUCLIDE NUMBER= 2

    NUCL. NUM.          1           2

    NUCL. NAME       NOBLE       IODINE

    RRATE BQ/H   0.110E+12   0.528E+11

    DEPO. VER.     0.0        0.003000
```

Because the release rates converted to those at shutdown is used in the program, the release rates shown here are defferent from those in the namelist.

```
******* BOUNDALY LAYERS INFORMATION *******
    HIGHT  0.0 M     MIXING      LAYER       500.0 M    PLANT BOUND. LAYER      1000.0 M      TOROPO.
    STABILITY                      D                                  D


******* STACK MET. DATA INFORMATION *******
    OBSERVED TIME(YYMMDDHHMMSS)  780823160000
    REL. POINT CELL NUM.(XYZ)    23  31   3
    RELEASE LEVEL WS.(M/S) UI=  1.72
                           VI= -1.52
                           WI= -0.02
    PRECIPITATION (MM)       0.0
    PLUME RISE HIGHT(M) =    0.0
    SITE MODEL HIGHT(M) = 50.00
```

Cell number which includes the release point.

Wind speed at the release point.

Model terrain height at the release point.

```
++++++++++++++++++++++++++++++++++++++++++++++++++++
+++ EFFECTIVE AND AVERAGE ENERGY OF MIXED NOBLE +++
+++ NUCLIDES (MEV )                             +++
+++                                             +++
+++  EFMIX  =      0.487      EVMIX  =     0.490 +++
+++                                             +++
++++++++++++++++++++++++++++++++++++++++++++++++++++
```

Effective and averaged energies of mixed noble gases.

```
++++++++++++++++++++++++++++++++++++++++++++++++++++
+++ EFFECTIVE AND AVERAGE ENERGY OF MIXED IODINE +++
+++ NUCLIDES ( MEV )                             +++
+++                                              +++
+++  EFMIX  =     1.310     EVMIX  =     0.804   +++
+++                                              +++
++++++++++++++++++++++++++++++++++++++++++++++++++++
1  0.1033390E+03 -0.2533981E+01  0.1537344E+03  23  31   3
2  0.1644092E+03 -0.7120950E+02  0.1662988E+03  23  30   4
3  0.2713135E+03 -0.9597658E+02  0.1500294E+03  23  30   4
4  0.3430867E+03 -0.1189053E+03  0.1620035E+03  24  30
5  0.3511873E+03 -0.1324273E+03  0.17
6  0.4738521E+03 -0.
7
```

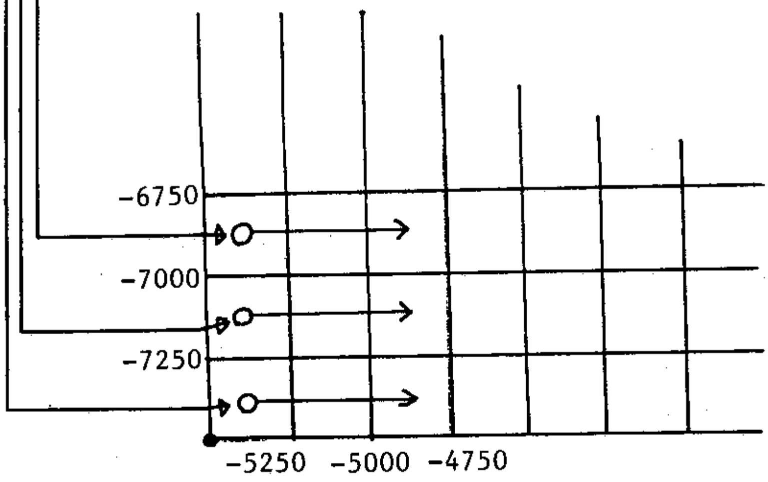
Effective and averaged energies of iodines.

Step No. X(m) Y(m) Z(m) Cell number

Debug write (position of particle No.1)

This means averaged concentration during the period from 16:00 to 17:00.

```
****************************************************************************************************
*** OUT-PUT DATA ** ACCUMLATION PEIOD   3600.0 S *** ACCUMULATION END TIME  780823170000 YYMMDDH
****************************************************************************************************

     *** Y-Z DISTRIBUTION ***


     *** CONCENTRATION DISTRIBUTION(GROUND LEVEL) (BQ/M**3) ***

NUCLID NAME : NOBLE

CELL WIDTH (M) =    250.0    250.0     50.0

  Y-DIRC.(M) (REL.P.:0.0) = -7500.0 J= 1
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
8.01E-04  8.96E-04  2.49E-03  2.82E-03  2.76E-03  1.80E-03  7.83E-04  8.65E-04  3.10E-04  2.60E-04

  Y-DIRC.(M) (REL.P.:0.0) = -7250.0 J= 2
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
1.00E-02  1.41E-02  1.51E-02  9.77E-03  8.23E-03  6.79E-03  7.44E-04  8.80E-04  3.81E-04  3.23E-04

  Y-DIRC.(M) (REL.P.:0.0) = -7000.0 J= 3
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
4.12E-02  6.27E-02  5.51E-02  2.99E-02  1.68E-02  1.39E-02  1.04E-04  5.59E-04  6.32E-04  5.70E-04

  Y-DIRC.(M) (REL.P.:0.0) = -6750.0 J= 4
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
4.89E-02  7.11E-02  6.03E-02  3.58E-02  2.11E-02  1.44E-02  0.0       2.19E-04  2.63E-04  1.60E-02

  Y-DIRC.(M) (REL.P.:0.0) = -6500.0 J= 5
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       5.82E-03  1.56E-03  1.48E-03
1.07E-01  1.0[illegible]E-02  4.00E-02  2.40E-02  1.04E-02  1.97E-04  1.74E-04  2.12E-04  1.13E-02

                                  - 6
                                            0.0       0.0       0.0       0.0       0.0
                                            0.0       0.0       0.0       0.0
                                                      5.82E-03  0.0
```

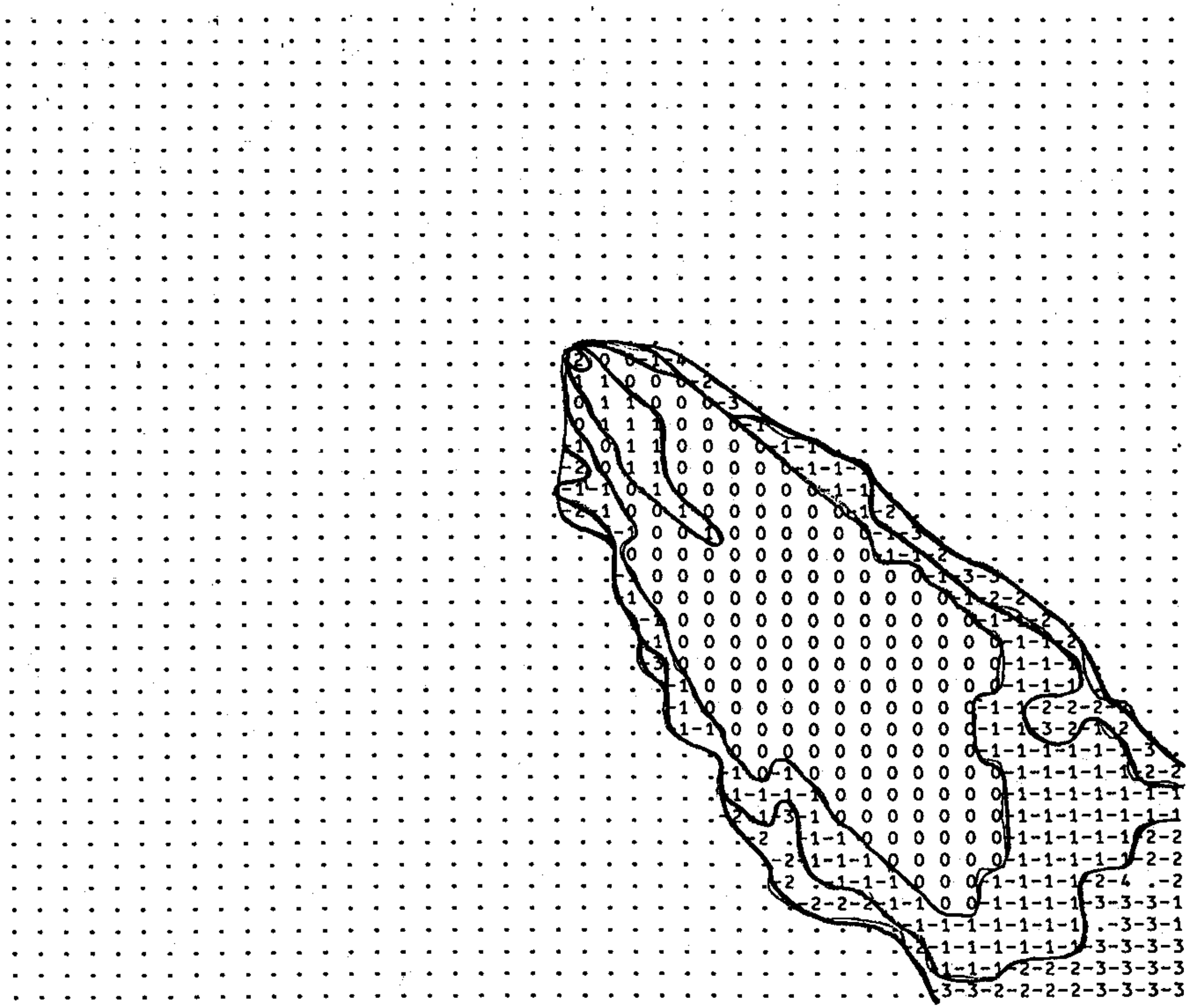


* Concentration map should be drawn like fig. A3.

(-5500, -7500)m

(see mesh information 3p before)

```
                         ****************************
                         ***                      ***
                         ***     DOSE  OUTPUT     ***
                         ***                      ***
                         ****************************


           *** AIR EXPOSURE RATE (NANO-GY/HOUR) ***


    *** J =  1
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       9
9.09E-04 2.65E-03 4.93E-03 7.95E-03 8.78E-03 8.97E-03 7.47E-03 1.07E-02 1.06E-02 7.20E-03

    *** J =  2
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       5.51E-04 4
4.51E-03 9.44E-03 1.26E-02 1.60E-02 1.62E-02 1.61E-02 1.28E-02 1.38E-02 1.42E-02 9.82E-03

    *** J =  3
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       3.05E-04 8.44E-04 3
1.21E-02 1.97E-02 2.25E-02 2.09E-02 1.77E-02 1.78E-02 1.45E-02 1.37E-02 1.44E-02 9.13E-03

    *** J =  4
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       1.10E-03 1.59E-03 7
2.08E-02 2.94E-02 2.68E-02 2.44E-02 2.30E-02 2.19E-02 1.95E-02 1.41E-02 1.12E-02 1.13E-02

    *** J =  5
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       1.58E-03 1.77E-03 4.37E-03 8.28E-03 2
3.77E-02 4.06E-02 3.42E-02 3.04E-02 3.06E-02 2.55E-02 1.94E-02 1.33E-02 1.19E-02 1.12E-02

    *** J =  6
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0
0.0       0.0       0.0       0.0       0.0       0.0       1.63E-03 3.32E-03 5.21E-03 1.19E-02 2.45E-02 4
5.55E-02 5.65E-02 4.81E-02 4.65E-02 4.25E-02 2.82E-02 2.29E-02 1.60E-02 9.01E-03 8.82E-03

    *** J =  7
0.0       0.                                        0.0       0.0       0.0       0.0       0.0       0.0       0
0.0                                                           0.0       0.0       0.0       0.0       0.0       0
                                                              2.61E-03 1.29E-02 1.40E-02 2.64E-02 4.88E-02 7
                                                                       1.53E-02 8.37E-03 6.03E-03
```



2 : 10^{2} - 10^{3} (Bq/m^{3})
1 : 10^{1} - 10^{2}
0 : 10^{0} - 10^{1}
-1 : 10^{-1} - 10^{0}
-2 : 10^{-2} - 10^{-1}
-3 : 10^{-3} - 10^{-2}
· : 0

Fig. A3 Surface concentration map of sample output.

Appendices 4 Error Message

1) EXPRESS-I, -IS

TIME PARAMETER UNMATCH ... ABNORMAL END or NTIMEC AND TIME NODE UNMATCH

Cause : No meteorological data at the objective time.

Measures: Comparison of time between namelist and meteorological data.

ERROR: WEIGHTS OF ALL THE OBSERVATORIES ARE 0.

PERHAPS OBSERVATORIES ARE NOT ARRANGED APPROPRIATELY.

(I,J,K)=XX,YY,ZZ

Cause : the weights of all the observatories for the grid (XX,YY,ZZ) are 0. This appears when the computational region is wide in spite of few observatories or only one or two data near the surface are available.

Measures: Extension of the representative area of each observatory. For example it is effective to use horizontal weighting factor for the synoptic region in Sub. WIND01 or to set the upper wind observatory artificially.

2) EXPRESS-II

ERROR STOP: METEOR. DATA AT OBJECTIVE TIME ARE NOT FOUND.

TIME=XXXXX

Cause : No meteorological data at the objective time.

Measures: Comparison of time between namelist and meteorological data.

ERROR STOP: WIND FIELD MESH AND TERRAIN MESH ARE UNMATCH.

Cause : The parameters of computational area, i.e., lower-left corner, mesh number and/or mesh width, are unmatch between wind field and EXPRESS-II.

Measures: Comparison of the parameters of computational area between EXPRESS-I and -II. Wind field mesh has a lower-left corner at the 2-mesh inside of lower-left corner of terrain mesh.

ERROR STOP: WIND FIELD AT OBJECTIVE TIME ARE NOT FOUND.

TIME=XXXXX

Cause : No wind field data at the objective time.

Measures: Comparison of time between namelist and wind field data.

```
ERROR ... ORDER OF NUCLIDE LIST IS UNMATCHED ...
```

Cause : The order of nuclides in the physical constant file is different from that in the data statement.

Measures: Correction of the order in the physical constant file.

```
ERROR ... XXXXXXXX IS NOT IN NUCLIDE FILE ...
```

Cause : Nuclide set in the namelist can not be treated.

Measures: Registration of nuclide in the data statement and the physical constant file.

```
ERROR(NUCCRE) REACTOR TYPE UNMATCH.  YOUR INPUT IS XXXXXX.
```

Cause : Reactor type set in the namelist can not be treated.

Measures: BWR and PWR are available.

```
===== ABEND (RESTART TIME UNMATCHED) =====
```

Cause : On and after the second calculation during the intermittent uses, the time in the particle file and the calculation starting time are unmatch.

Measures: Calculation must be started from the time in the file.

```
! ERROR (RDDATA) .. XXXXXXXXXXXX (TIME UNMATCH)
```

Cause : On and after the second calculation during the intermittent uses, the last time in the XXXXXXXX file and the calculation starting time are unmatch.

Measures: Calculation must be started from the last time in the file.

Appendices 5 List of Programs

EXPRESS-I source file	EX1.FORT77
EXPRESS-IS source file	EX1S.FORT77
EXPRESS-II source file	EX2.FORT77
EXPRESS-I,IS,II include file	EXPRESS.INC.FORT77
EXPRESS-I,-IS namelist	EXNAME1.DATA
EXPRESS-II namelist	EXNAME2.DATA
Geological file	EXTOPO.DATA
Meteorological file	EXMET.DATA
Physical constant file	EX.NUCLIDE.DATA
Isotopic composition file	EX.NUCCRE.DATA
KDE concentration file	EX.PFCONC.DATA
KDE dose file	EX.PFDOSEN.DATA
Terrain barrier file	EXBRA.DATA
Wind field file	EXWIND.OPEN.DATA
Air concentration file	EX.CONC.DATA
Deposition file	EX.DEPO.DATA
Air dose rate file	EX.RDDOSE.DATA
γ-external dose file	EX.EXDOSE.DATA
Thyroid dose file	EX.THDOSE.DATA
Internal dose file	EX.INDOSE.DATA
Particle file	RWFILE.DATA
Output data information file	EX.OUTPRM.DATA
EXPRESS-I print out	EX1OUT.DATA
EXPRESS-II print out	EX2OUT.DATA
EXPRESS-I JCL	EX1.CNTL
EXPRESS-II JCL	EX2.CNTL

Appendices 6 Specification of Programs

1) Programming language used --- FORTRAN77
2) Computer for which program is designed --- FACOM M-780, Fujitsu Ltd.
3) Test computer --- VAX-6000, FACOM A340 (work station)

   The correction of external function for random number which is used in EXPRESS-II and the number of 1.E-76 which is also used in EXPRESS-II explicitly must be changed to install the program in the work station.
4) Typical running time.

	FACOM M-380 (main flame)	FACOM A340 Σ (EWS)
EXPRESS-1	10.5 sec	195 s
	(11.33)	(-)
EXPRESS-IS	7.62 sec	-
	(11.67)	(-)
EXPRESS-II	5.19 sec	175 sec
	( ): ICYCL=0	

   CPU times for EXPRESS-I,-IS are for one objective analysis.

   CPU time for EXPRESS-II is for one-hour simulation.
5) Main storage used.

   EXPRESS-I : 6.8 MB
   EXPRESS-IS: 8.6 MB*
   EXPRESS-II: 2.0 MB

   *: The main storage for EXPRESS-IS exceeds 8.0 MB. It is because the parameters NEARS and WEIGHT in the weight file are prepared for u- and v-components of wind fields. Thus, if the NEAR and WEIGHT for u-component are used for the v-component interpolation, the main storage is decreased to 7.5 MB and the results are probably almost the same.