SUPPLEMENTAL MATERIALS

Supplemental S1

Rapid Source Inversion Method based on the Lagrangian model (RSIML)

According to the Lagrangian theory, spatial and temporal distribution of concentration may be achieved based on the statistics of particle or puff distributions in diffusion simulations. Once the time step and the calculation range are fixed, computing time only depends on the total number of particles. Thus, we can assume that the source strong is 1, and we can determine the concentration contribution rate α for each time in the diffusion region at any position without changing the total number of particles. If a linear relationship between the source intensity and concentration is observed, the concentration at time t at a specific position is:

$$c(x,y)=\int_0^t \alpha(x,y,t)s(t)\mathrm{d}t \tag{1}$$

For air pollution nuclear accidents, the predicting concentration and monitoring concentration of radioactive substances at the monitoring point j are $c(x_j,y_j)$ and $c_o(x_j,y_j)$, respectively (Bq / m^3), s_i is the release rate of a certain radioactive substance at time i, and $\alpha_{i,j}$ is the concentration contribution rate of the source s_i for the monitoring result j:

$$c(x_j,y_j)=\sum_{i=1}^{M}\alpha_{i,j}s_i \tag{2}$$

$$J=\min\sum_{j=1}^{N}[c(x_j,y_j)-c_o(x_j,y_j)]^2 \tag{3}$$

We then solve for s_i for certain radioactive substances, where $i=1,\cdots,M$. We let

$$f(s_i)=\sum_{j=1}^{N}[\sum_{i=1}^{M}\alpha_{i,j}s_i-c_o(x_j,y_j)]^2$$

According to the principle of least squares method, we could obtain:

$$\frac{\partial f(s_i)}{\partial s_i} = 0 \tag{4}$$

Let $c_o(x_j, y_j) = c_{jo}$, and we could obtain:

$$\begin{aligned}
\frac{\partial f(s_1)}{\partial s_1} &= \sum_{j=1}^{N} 2(\alpha_{1,j}s_1 + \alpha_{2,j}s_2 + \cdots + \alpha_{M,j}s_M - c_{jo})\alpha_{1,j} \\
&= \alpha_{1,1}\alpha_{1,1}s_1 + \alpha_{2,1}\alpha_{1,1}s_2 + \cdots + \alpha_{M,1}\alpha_{1,1}s_M - c_{1o}\alpha_{1,1} \\
&+ \alpha_{1,2}\alpha_{1,2}s_{1,k} + \alpha_{2,2}\alpha_{1,2}s_2 + \cdots + \alpha_{M,2}\alpha_{1,2}s_M - c_{2o}\alpha_{1,2} \\
&+ \cdots \\
&+ \alpha_{1,N}\alpha_{1,N}s_1 + \alpha_{2,N}\alpha_{1,N}s_2 + \cdots + \alpha_{M,N}\alpha_{1,N}s_M - c_{No}\alpha_{1,N} \\
&= (\alpha_{1,1}\alpha_{1,1} + \alpha_{1,2}\alpha_{1,2} + \cdots + \alpha_{1,N}\alpha_{1,N})s_1 + (\alpha_{2,1}\alpha_{1,1} + \alpha_{2,2}\alpha_{1,2} + \cdots + \alpha_{2,N}\alpha_{1,N})s_2 \\
&+ \cdots + (\alpha_{M,1}\alpha_{1,1} + \alpha_{M,2}\alpha_{1,2} + \cdots + \alpha_{M,N}\alpha_{1,N})s_M - (\alpha_{1,1}c_{1o} + \alpha_{1,2}c_{2o} + \cdots + \alpha_{1,N}c_{No}) \\
&= 0
\end{aligned}$$

$$\begin{aligned}
\frac{\partial f(s_2)}{\partial s_2} &= \sum_{j=1}^{N} 2(\alpha_{1,j}s_1 + \alpha_{2,j}s_2 + \cdots + \alpha_{M,j}s_M - c_{jo})\alpha_{2,j} \\
&= \alpha_{1,1}\alpha_{2,1}s_1 + \alpha_{2,1}\alpha_{2,1}s_2 + \cdots + \alpha_{M,1}\alpha_{2,1}s_M - c_{1o}\alpha_{2,1} \\
&+ \alpha_{1,2}\alpha_{2,2}s_1 + \alpha_{2,2,k}\alpha_{2,2}s_2 + \cdots + \alpha_{M,2}\alpha_{2,2}s_M - c_{2o}\alpha_{2,2} \\
&+ \cdots \\
&+ \alpha_{1,N}\alpha_{2,N}s_1 + \alpha_{2,N}\alpha_{2,N}s_2 + \cdots + \alpha_{M,N}\alpha_{2,N}s_M - c_{No}\alpha_{2,N} \\
&= (\alpha_{1,1}\alpha_{2,1} + \alpha_{1,2,k}\alpha_{2,2} + \cdots + \alpha_{1,N}\alpha_{2,N})s_1 + (\alpha_{2,1}\alpha_{2,1} + \alpha_{2,2}\alpha_{2,2} + \cdots + \alpha_{2,N}\alpha_{2,N})s_2 \\
&+ \cdots + (\alpha_{M,1}\alpha_{2,1} + \alpha_{M,2}\alpha_{2,2} + \cdots + \alpha_{M,N}\alpha_{2,N})s_M - (\alpha_{2,1}c_{1o} + \alpha_{2,2}c_{2o} + \cdots + \alpha_{2,N}c_{No}) \\
&= 0
\end{aligned}$$

$$\vdots$$

$$\begin{aligned}
\frac{\partial f(s_M)}{\partial s_M} &= \sum_{j=1}^{N} 2(\alpha_{1,j}s_1 + \alpha_{2,j}s_2 + \cdots + \alpha_{M,j}s_M - c_{jo})\alpha_{M,j} \\
&= \alpha_{1,1}\alpha_{M,1}s_1 + \alpha_{2,1}\alpha_{M,1}s_2 + \cdots + \alpha_{M,1}\alpha_{M,1}s_M - c_{1o}\alpha_{M,1} \\
&+ \alpha_{1,2}\alpha_{M,2}s_1 + \alpha_{2,2}\alpha_{M,2}s_2 + \cdots + \alpha_{M,2}\alpha_{M,2}s_M - c_{2o}\alpha_{M,2} \\
&+ \cdots \\
&+ \alpha_{1,N}\alpha_{M,N}s_1 + \alpha_{2,N}\alpha_{M,N}s_2 + \cdots + \alpha_{M,N}\alpha_{M,N}s_M - c_{No}\alpha_{M,N} \\
&= (\alpha_{1,1}\alpha_{M,1} + \alpha_{1,2}\alpha_{M,2} + \cdots + \alpha_{1,N}\alpha_{M,N})s_1 + (\alpha_{2,1}\alpha_{M,1} + \alpha_{2,2}\alpha_{M,2} + \cdots + \alpha_{2,N}\alpha_{M,N})s_2 \\
&+ \cdots + (\alpha_{M,1}\alpha_{M,1} + \alpha_{M,2}\alpha_{M,2} + \cdots + \alpha_{M,N}\alpha_{M,N})s_M - (\alpha_{M,1}c_{1o} + \alpha_{M,2}c_{2o} + \cdots + \alpha_{M,N}c_{No}) \\
&= 0
\end{aligned}$$

Let $A = \begin{vmatrix} \alpha_{1,1} & \alpha_{1,2} & \cdots & \alpha_{1,N} \\ \alpha_{2,1} & \alpha_{2,2} & \cdots & \alpha_{2,N} \\ \cdots & \cdots & \cdots & \cdots \\ \alpha_{M,1} & \alpha_{M,2} & \cdots & \alpha_{M,N} \end{vmatrix}$, thus $A^{\mathrm{T}} = \begin{vmatrix} \alpha_{1,1} & \alpha_{2,1} & \cdots & \alpha_{M,1} \\ \alpha_{1,2} & \alpha_{2,2} & \cdots & \alpha_{M,2} \\ \cdots & \cdots & \cdots & \cdots \\ \alpha_{1,N} & \alpha_{2,N} & \cdots & \alpha_{M,N} \end{vmatrix}$

Let $S = \begin{vmatrix} s_1 & s_2 & \ldots & s_M \end{vmatrix}^{\mathrm{T}}$, $C_o = \begin{vmatrix} c_{1o} & c_{2o} & \ldots & c_{No} \end{vmatrix}^{\mathrm{T}}$

and then we could obtain:

$$AA^{\mathrm{T}}S = AC_o \qquad (5)$$

Therefore, according to equation (5), we could calculate the source S as long as we come to the matrix A of the concentration contribution rate based on the Lagrangian dispersion model and the vector C_o of the monitoring results.

A test case using the RSIML

Supposed the matrix A of the concentration contribution rate

$$A(x, y) = \left|\mathrm{random}('\mathrm{Normal}',1,0.1,1,1)\right|[\mathrm{randn}(x)+10]\frac{1}{10\sqrt{2\pi}}e^{\frac{-(y-50)^2}{200}}$$

the source S_0 meets Poisson distribution

$$S_0(\lambda) = S_0(X = k) = \frac{\lambda^k}{k!}e^{-\lambda}, \quad \text{where } \lambda = 4.02$$

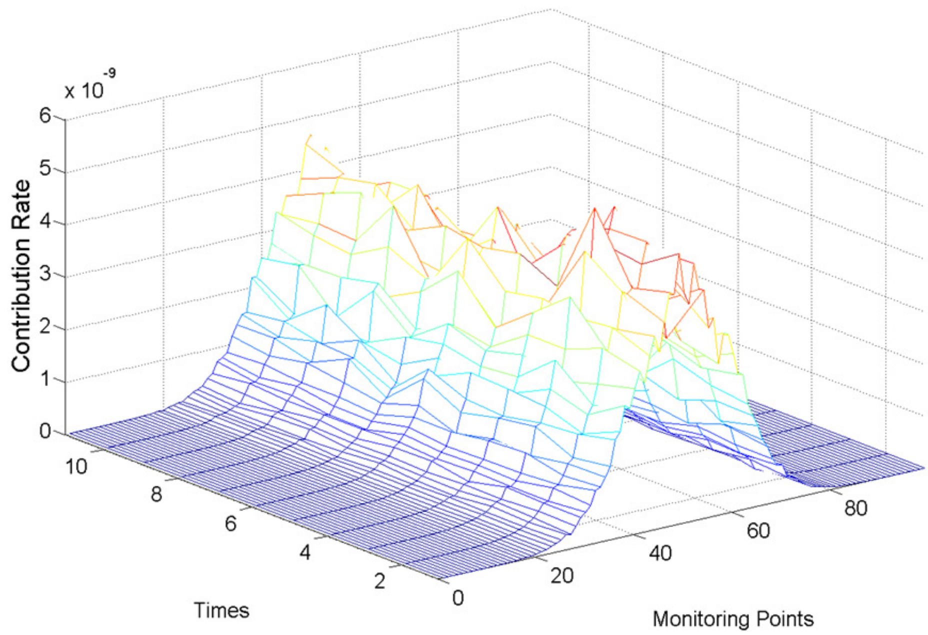

Fig. 1 The matrix A of the concentration contribution rate

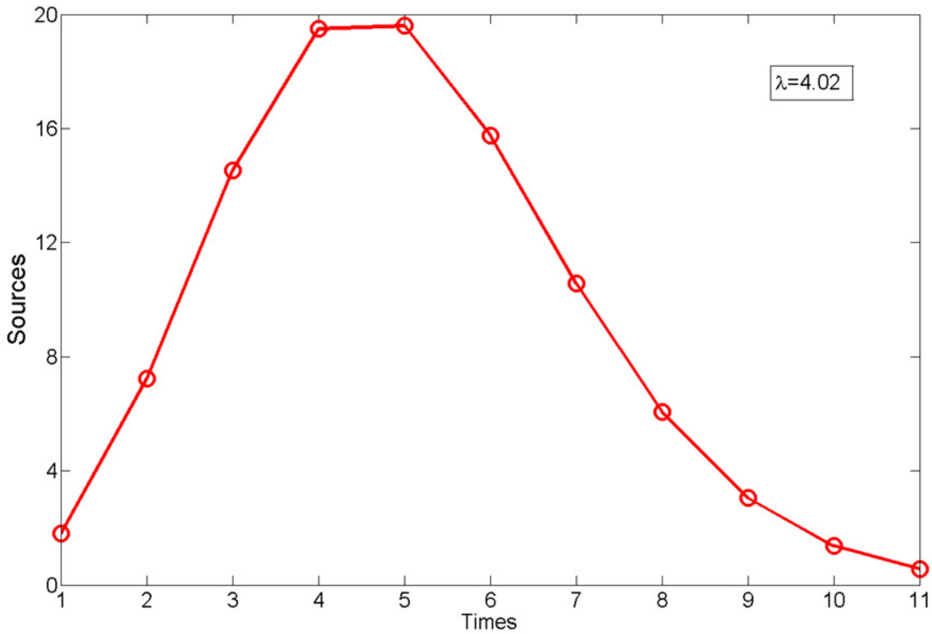

Fig. 2 The source S_0 meets Poisson distribution

(1) Sensitivity analysis of the inversed sources to the error of monitoring results

The monitoring results C are multiplied by the variance of 0.01 normal random number, namely $C = C_0 \cdot \text{random('Normal'},1,0.01,1,99)$, and then the results of source inversion are shown as Fig.3, the relative error δ_C of S and S_0 is 1.5%, their correlation coefficient R_C is 0.971.

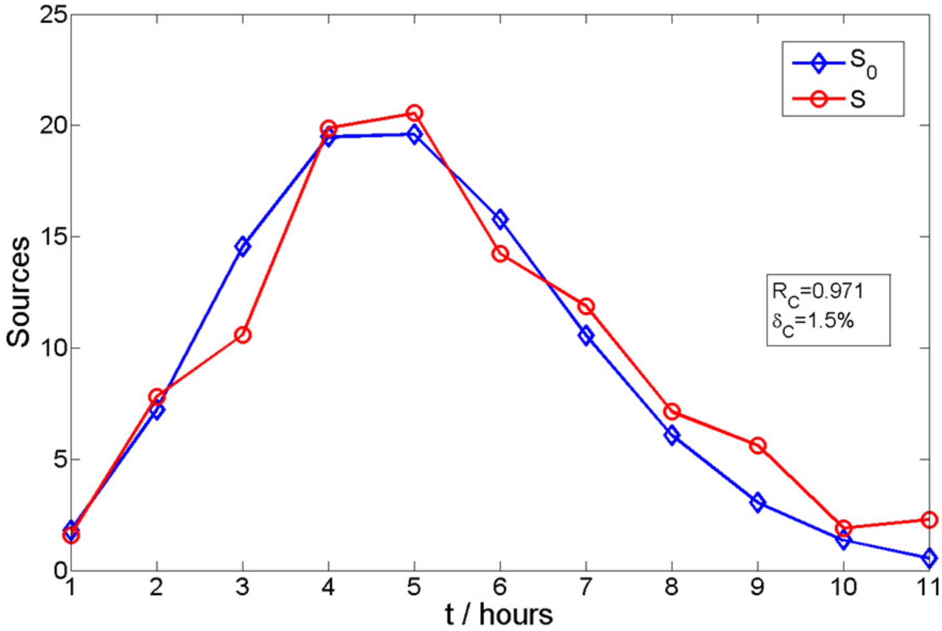

Fig. 3 Sensitivity analysis of the inversed sources to the error of monitoring results in the test case

(2) Sensitivity analysis of the inversed sources to the error of the concentration contribution rate

The matrix A_1 of the concentration contribution rate is multiplied by the variance of 0.01 normal random number, namely $A_1 = A \cdot \mathrm{random}('\ \mathrm{Normal}'\ ,1,0.01,11\ ,99)$ and the results of source inversion are shown as Fig.4, the relative error δ_A of S and S_0 is 1.5%, and their correlation coefficient R_A is 0.992.

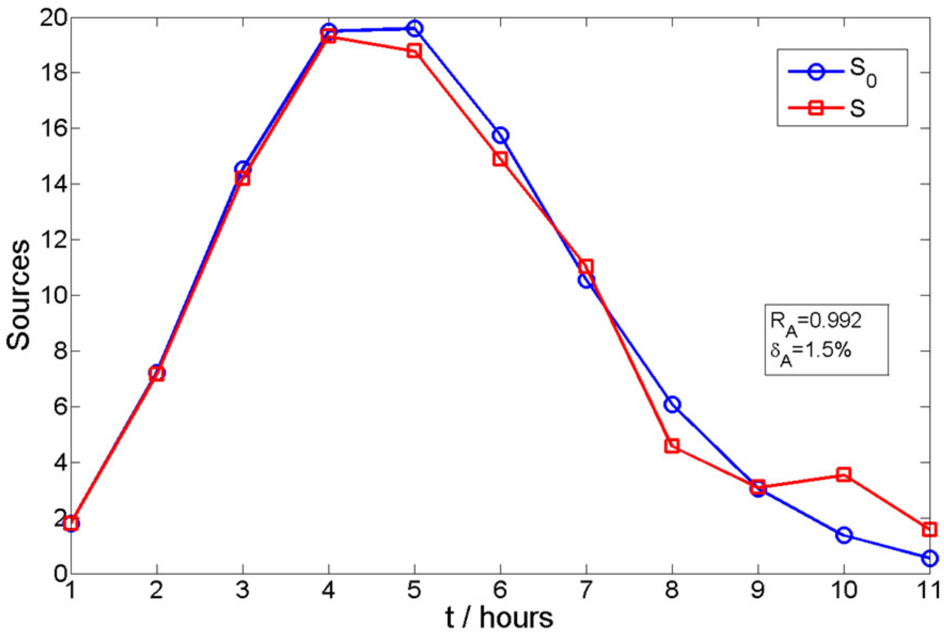

Fig. 4 Sensitivity analysis of the inversed sources to the error of the concentration contribution rate in the test case

Supplemental S2

Theoretical Framework of APPOCS

1. General formulation of the question

The spread of nuclear accidents are closely related to natural conditions and human activities; therefore, we must examine natural and human aspects of the control variables. If we assume the prediction of a nuclear accident is calculated based on the degree of harm to the receptor from known causes (risk sources, natural conditions, etc.), then nuclear emergency control is regulating the source or receptor (accident source control, warning, evacuation, protection, decontamination, monitoring, medical treatment, etc.) to achieve the required results. Due to a nuclear accident, large quantities of radioactive material are released. To control the hazards, we need to control the accident. Obviously, an increased control intensity decreases the environmental impact and casualties caused by the accident. Conversely, a decreased control intensity (even with a low loss of control) increases the harm caused by the accident. Thus, a balance is required; that is, under the premise of meeting the control objectives of the accident, the loss of control and accident costs must be minimized. Mathematical descriptions of the problem are as follows:

When conducting nuclear accident emergency control, we set the natural environment-related variables (such as weather, terrain and other factors) as $D(r,t)$, which changes with spatial point r and time t. Variables related to the human and social factors (such as emergency response costs, accident losses, and other factors) are $E(r,t)$, and these variables are affected through $D(r,t)$ based on the impact of the accident source. Evolution of the natural environment $D(r,t)$ is affected by itself, the natural process variable $V(r,t)$, and the human and social variable $E(r,t)$. The differential equations are as follows:

$$\frac{\partial D}{\partial t} = L(D,V,E,t) \qquad (1)$$

The initial condition can be described as:

$$D(r,t)\big|_{t=t_0} = D^0(r) \tag{2}$$

Boundary conditions can be described as:

$$\Lambda(D,G,t)\big|_{\partial\Omega} = G(D,U,t) \tag{3}$$

Where D^0 is the initial dose of radioactive material in space and D is the dose of radioactive material at different times in space. The process is calculated from the diffusion model, including the transmission, deposition and transformation, t_0 is the initial time of nuclear accident hazards, L is space differential operator, $\partial\Omega$ is the border of space Ω where the nuclear accident occurs, Λ is the boundary condition operator, with function G in addition to D on the boundary, and depends on the nuclear accident source or control rates U, as well as the economic or administrative costs. Here, we set the source and measures on the boundary (such as the ground). The two functions $G_1(U)$ and $G_2(D)$, $G_1(U)$ represent the economic cost of control. $G_2(D)$ is used to consider the loss of the accident itself. Clearly, nuclear accident emergency control is limited by social competence, such as the number of emergency units, professionalism, location, number, and sophistication of emergency equipment, and the type and quantity of emergency supplies. These restrictions can be expressed as:

$$\|E(r,t)\|_e \le D_C \tag{4}$$

Where D_C is restriction, which we consider it constant. Meanwhile, in nuclear accidental emergencies, the public's health and safety is the first priority, and we must control the source of the accident through decontamination of contaminated areas, determining protocols required to achieve a certain degree of environmental health standards after decontamination, avoiding high dose regions during the evacuation, and (if people have to enter a high dose region) ensuring that individuals protect themselves as much as possible. For these requirements, we put these environmental health restrictions unified as:

$$\left\| D - D_p \right\|_p \leq D_0 \tag{5}$$

Where D_0 is dose threshold and D_p can be considered dose background values. The goal of Nuclear Emergency optimal control is to determine the optimal control scheme within the limits of the conditional expression (4) and (5) and minimize the contingency operations costs and accidental damage, that is take a function J of G_1 and G_2 as the minimum.

$$J(G_1, G_2) = \min$$

$$s.t. \quad \frac{\partial D}{\partial t} = F(D, V, T, \ldots) + Q_0(1-U) \tag{6}$$

In which, L can be written in two parts; one is the description of the radioactive material advection-diffusion process operator, F , and another is the intensity of the Q_0 leak source $Q_0(1-U)$, U is the source control factor.

We may gain the matrix B of the dose contribution rate based on the Lagrangian dispersion model, and then obtain the dose contribution after the optimal control:

$$d(x, y, z; t) = BQ_0(1-U) \tag{7}$$

2. Nuclear emergency optimal control model

Based on a combination of G_1 and G_2, the accident losses and emergency actions costs, as the objective function, use the Natural Cybernetics and adjoint method to optimize the emergency operations and determine the optimal emergency control scheme. In the process of emergency optimal control, feedback relationships exist between emergency control scheme and loss of accident and emergency action costs. Using distributed computing methods, we generate the accident source control feedback to the accident source term of the diffusion model, thus calculating the development trend of the accident hazards under the new control scheme. The optimizing process control is to generate the optimal real-time emergency action plan based on the objective function of the minimum loss due to accidents and emergency operations costs. The whole system reflects the actual situation of nuclear accidents in complex systems, including dynamics and economic principles, emergency personnel, equipment, materials and technology restrictions, and also considers the socio-economic impact.

The nuclear accident loss can be divided into two parts: i) emergency action costs when dealing with a nuclear accident; ii) losses caused by the nuclear accident itself. We divided the emergency action costs variable into three components; emergency unit, emergency equipment, and emergency-depleting substances. Taking into account that the boundary condition operator Λ is often a direct reflection of the intensity of emission sources, contingency operations cost functions can be described as:

$$G_1(Eu, Eq, Em) = \sum_{i=1}^{N_1} t_i Eu_i + \sum_{i=1}^{N_2} \tau_i Eq_i + \sum_{i=1}^{N_3} Em_i \quad (8)$$

Where $G_1(Eu, Eq, Em)$ is cost of action, Eu_i is the i branch emergency unit cost per unit time, $1 \leq i \leq N_1, N_1$ is a positive integer greater than or equal to 1; t_i is the response time of the i branch measured in hours or days, Em_i represents the value of the i class emergency-depleting substances, $1 \leq i \leq N_3$, and N_3 is a positive integer greater than or equal to 1. We can separate the cost of the nuclear accident itself into three components; namely, loss of property in contaminated area, personal injury, and the ecological environment damage. The accident loss function can be described as:

$$G_2(Bd, Pd, En) = \sum_{i=1}^{N} s_j \lambda_j Bd(j) + \sum_{i=1}^{N} \sum_{k=1}^{M} \eta_k Pd(j,k) + \sum_{i=1}^{N} s_j En_j \quad (9)$$

Where $Bd(j)$ is the gathering degree of property in j area, $1 \leq j \leq N$, N is a positive integer greater than or equal to 1, λ_j is the property loss coefficient in the j contaminated area, s_j is the size of j contaminated area, $Pd(j,k)$ is the number of people subjected to pollution hazard level k in j contaminated area, η_k is the compensation costs for each person subjected to pollution hazard level k (including medical expenses, pensions, mental damages, etc.), and En_j is the loss of ecological environment in the j contaminated area.

Thus, the objective function J of total loss of nuclear accidents is:

$$J = G_1(Eu, Eq, Em) + G_2(Bd, Pd, En) \quad (10)$$

Control objective is to minimize the objective function J of total loss of nuclear accidents, when the dose finally reaches a certain threshold within the control area, namely:

$$\min J = \min[G_1(Eu, Eq, Em) + G_2(Bd, Pd, En)]$$
$$s.t. \quad d(x_j, y_j, z_j) \leq d_{j0}, j = 1,2,\ldots,N$$
(11)

Where (x_j, y_j) are the horizontal coordinates of the j geographic regions and z_j is the vertical coordinate.

We use penalty function method to construct the optimal control model for the loss of nuclear accident and the cost of emergency operations:

$$\begin{aligned} J_{new} &= G_1(Eu, Eq, Em) + G_2(Bd, Pd, En) \\ &+ \gamma \sum_{j=1}^{N} w\left[d\left(x_j, y_j\right) - d_{j0}\right] \end{aligned} \quad (12)$$

In which $$w(p) = \begin{cases} p^2 & p \geq 0 \\ p^2 \exp(-p^2 / \beta) & p < 0 \end{cases} \quad (13)$$

γ , β is the coefficient; its value can be adjusted according to the actual situation. Using optimization algorithms to solve this model, we can obtain the optimal control scheme.

3. Model parameter calculation method

3.1 Accident source control efficiency calculation

Accident source control includes plugging the leak source, decontamination, and other measures (such as cooling a reactor that may leak). Control measures differ for different sources, but typically the greater the intensity of the control the smaller the incident source intensity. When the source term control reaches a certain level, control costs may increase sharply with little effect and it is necessary to perform sensitivity analysis to control factors, extracting critical control factor, and solving the best value for the key factor. According to the key influence factors and values, it is possible to quantify the costs of emergency action required for the emergency unit, emergency equipment, and emergency-depleting substances, etc. Meanwhile, the incident source control parameters are returned to the source term model, revealing a new source strength of the incident. Based on these results, we can determine U in formula (6).

3.2 Calculation of accidental loss parameters

By solving the formula (7), we can determine the size of endangered areas S_H .

$$S_H = \iint_{\partial\Omega} s(x, y, z; t)\mathrm{d}x\mathrm{d}y \qquad (14)$$

Where, $s(x, y, z; t) = \begin{cases} 1 & d(x, y, z; t) \geq d_0 \\ 0 & d(x, y, z; t) < d_0 \end{cases}$

d is dose (Bq·s / m^3), $\rho(x, y, z; t)$ is population density distribution and d_0 is dose threshold. The number of persons needed to covert

$$N_{\mathrm{COV}} = \mathrm{int}(\iint_{\partial\Omega} s(x, y, z; t)\rho(x, y, z; t)\mathrm{d}x\mathrm{d}y\mathrm{d}z \qquad (15)$$

Where, $s(x,y,z;t)=\begin{cases}1 & d(x,y,z;t)\ge D_{\text{COV}}\\ 0 & d(x,y,z;t)< D_{\text{COV}}\end{cases}$

Where D_{COV} is the covert threshold dose. Similarly, N_{eva}, the number of people that need to evacuate, and N_{iod}, the maximum number of iodine available, can be obtained. In addition, according to the number of personnel contaminated and distribution of ecological environment and property within the range of hazards, the total loss of the accident itself can be calculated.

3.3 Calculation of emergency action consideration parametric

We divided the area to be evacuated into several parts and defined the equivalent length of evacuation as:

$$L=\sum_{j=1}^{m}\sum_{i=1}^{n}K_i l_i(1+\lambda d) \tag{16}$$

Where m is the total number of parts to be evacuated, n is the number of roads in the evacuation plan, and K_i is the level of difficulty when passing road i. Since there is more than one vehicle on the road simultaneously, the level of difficulty when passing the road is proportional to the number of vehicles passing through the same section of the road, l_i is the length of road i, and λd is the penalty function. According to the scope of hazards, endangering time, and the calculation results of formula (16) and other data, we calculated the number of people and amount of equipment needing protection and decontamination, and other emergency personnel and equipment required while warning, evacuation, and monitoring during the evacuation process. The time of protection and lifting is calculated as follows:

The radioactive substances will not cause harm to people after arriving in a period of time, but would cause injury when the dose reaches a certain threshold. Therefore, the protection time t_P is the time to reach the hazards threshold dose. Theoretical expression is expressed as:

$$d(x,y,z,t_p)=D_{\text{cov}} \tag{17}$$

Similarly, we may calculate the evacuation time t_{eva} and the taking iodine time t_{iod}.

Formula (17) is the variable of diffusion model theory equations, and we can determine the time when poison reaches the hazards threshold dose by solving the diffusion model; namely, the protection time t_P. Lifting protection time is for the protection personnel. When the dose of radioactive substances in the air is below a protection threshold dose D_{DP} (we ignored the impact of ground deposition of short-term external irradiation), it can be considered that exposed people and unprotected people experience the same risk. Thus, time to lift the protection is t_{DP}, the time when the dose of radioactive substances in the air is below the D_{DP}. Theoretical expression is expressed as:

$$d(x,y,z;t_{DP}) = D_{DP} \qquad (18)$$

Where D_{DP} is threshold dose without hazards . We can determine the time when the concentration of radioactive substances in the air is below the threshold dose without harm from formula (18); namely, the time to lift protection, t_{DP}. We can also calculate the costs of emergency action such as emergency units, emergency equipment, and emergency-depleting substances by solving the emergency response parameters. For particularly significant nuclear accidents, common communication infrastructure may not meet the emergency needs. Thus, we may require emergency communication equipment.

D_{COV}, D_{eva}, D_{iod}, and D_{DP} are obtained by formula (19)

$$D_k = DC_k + DI_k + DG_k \qquad (19)$$

Where, D_{eva} is used by calculating t_{eva} represents the evacuation threshold dose, D_{iod} is used by calculating t_{iod} represents the taking iodine threshold dose, D_k represents the organ k acceptable total dose, DC_k represents the organ k acceptable plume external radiation dose rates（Sv）, DI_k represents the organ k acceptable plume internal radiation dose rates（Sv）, DG_k represents the organ k acceptable ground deposition internal radiation dose rates（Sv）.

The plume external radiation dose rates DC_k can be calculated by formula (20)

$$DC_k = \left(\sum_i d_i \cdot DCF_{ik} \right) \cdot SFC \qquad (20)$$

Where, d_i represents the air near ground radiation dose of radionuclide i（Bq·s / m^3）obtained by formula (7), DCF_{ik} represents the organ k dose conversion factor of radionuclide i [Sv（Bq·s / m^3）$^{-1}$], and SFC represents the shielding factor of buildings (dimensionless).
The plume internal radiation dose rates DI_k can be calculated by formula (21)

$$DI_k = \left(\sum_i d_i \cdot DFI_{ik} \right) \cdot H_R \cdot SFI \qquad (21)$$

Where, H_R represents the human respiratory rate(m^3 / s), DFI_{ik} represents the organ k inhaled dose conversion factor of radionuclide i (Sv / Bq), and SFI represents the shielding factor of inhalation radiation (dimensionless).
The ground deposition internal radiation dose rates DG_k can be calculated by formula (22)

$$DG_k = \left(\sum_i D_i \cdot DCFG_{ik} \right) \cdot SFG \qquad (22)$$

Where, $DCFG_{ik}$ represents the organ k the ground deposition radiation dose conversion factor of radionuclide i [Sv（Bq·s / m^2）$^{-1}$], and SFG represents the shielding factor of ground deposition radiation (dimensionless).

Overall, according to the hazards prediction for personnel and the environment, we developed a reasonable accidents source control, alert, evacuation, monitoring, protection, decontamination, medical treatment and other emergency response plan, while sending these critical data back to the emergency operations cost function G_1, confirmed the type and number of emergency units, emergency preparedness, emergency-depleting substances and other elements, and calculated the contingency operations costs. Similarly, we sent the results of infected people, contaminated areas, and the extent back to the accident loss function G_2 to provide critical data for calculating accident damage.