DISPERSION OF RADIONUCLIDES AND RADIOLOGICAL DOSE COMPUTATION OVER A MESOSCALE DOMAIN USING WEATHER FORECAST AND CFD MODEL

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Abstract

The atmospheric dispersion of pollutant has remained an intricate problem because of the inherent complexities associated with the meteorological parameters responsible for the dispersion of pollutants. Conventionally simplified approaches, such as Gaussian Plume or puff based models, are used for the assessment of environmental impact due to atmospheric releases of pollutant. However, the assumptions made in such approaches are difficult to realize even for simple terrain conditions. Hence such models are generally being used with conservative assumptions to get upper limit estimation of the impact. To improve upon such simplified approaches, 4-dimensional wind field for the site under consideration is generated using mass consistent approaches, and the wind field thus generated is passed onto the suitable Eulerian based or Lagrangian based atmospheric dispersion models. This approach is relatively attractive, however the reliability of the wind field depends on the spatial and temporal density of meteorological measurements and more over, the wind filed satisfies only mass conservation law. With easy availability of fast computing facilities, it has now become possible to make use of Computational Fluid Dynamics (CFD) based model for generating 4-dimensional wind field for a given topographic conditions that satisfies conservation of mass, momentum and energy. Like mass consistent models, CFD based models also depend on the spatial and temporal density of meteorological measurement. To overcome this difficulty and also to make use of CFD based model in a predictive mode, a CFD based model, i.e. *fluidyn*-PANEPR, is coupled with Numerical Weather Prediction (NWP) model, i.e. MM5, as well as with a radiological dose assessment model, and the results are presented in this paper for a hypothetical case study.

1. INTRODUCTION

Study on atmospheric dispersion of pollutants has got impetus in recent times due to rapid industrialization throughout the world. The atmospheric dispersion models are required before the installation of any industrial facility to check the impact on surrounding environment due to the proposed industry, during the operation of industry to check compliance with the stipulated limits specified by the regulatory authority, and during accidental conditions for the better management of emergency conditions.

For Nuclear Power Plants (NPPs) in India, the meteorological conditions of the proposed NPP site are monitored for several years prior to the installation of the facility, and environmental impact studies are performed for the site. It is known that the routine releases of radioactive pollutants from NPPs are so low that monitoring of environmental concentrations become difficult and many a times it is unachievable due the minimum detection limits of the measurement systems. In such cases, the environmental impact due to NPPs is modeled and the assessments are carried out with measured meteorological parameters at the site. The accidental conditions, with a negligible probability of occurrence, is been given a special consideration in India. Emergency preparedness for each NPP site is well defined and the actions to be taken under such conditions are well documented. The preparedness to handle the accidental conditions is checked through mock drills at regular interval for each site. It is for the accidental conditions, it was thought of to make use of Numerical Weather Prediction (NWP) models to have forecast of radiological conditions in case of any accidental releases.

In order to develop a system that can give radiological forecast in case of accidental conditions, the MM5 (Dudhia et. al.,2005)-the fifth generation mesoscale model developed by Pennsylvania State University and National Centre for Atmospheric Research, USA, was identified as the suitable Numerical Weather Prediction model for mesoscale applications. For atmospheric dispersion of pollutants a CFD based model, *fluidyn*-PANEPR, was selected. The MM5 generated flow field also satisfies conservation of mass, momentum and energy, however, the finest grid resolution that can be achieved with MM5 is around 1 km. In order to generate wind field at finer resolution than 1 km, satisfying basic conservation laws, a CFD based model was selected. The following sections briefly describe the models used in the present study.

1.1 MM5 MODELING SYSTEM

The MM5 modeling system uses terrain following σ coordinate system. In this, the lowest grid level follows the terrain while the upper surface is flat. Intermediate levels progressively flatten as the pressure decreases toward the chosen top pressure. A dimensionless quantity σ is used to define model vertical levels where

$$\sigma = \frac{(P-P_t)}{(P_s-P_t)} \tag{1}$$

here P is the pressure, P_t is a specified constant top pressure, P_s is the surface pressure.

In the horizontal direction, the model uses Arakawa-Lamb B-staggering of the velocity variables with respect to the scalars. In this, the scalars (Temperature, Specific humidity etc.) are defined at the centre of the grid square, while the eastward (u) and northward (v) velocity components are collocated at the corners. The model solves basic conservation laws in terrain following coordinate system once initialized with initial conditions and supported with boundary conditions from Global Weather Forecast Systems. The model has capability to assimilate locally measured data using grid nudging or analysis nudging technique. The model also has facility to incorporate locally measured data through Four Dimensional Data Assimilation Technique. The model has capability to run multiple nests simultaneously with up to nine domains running at the same time and completely interacting with each other. The nested domain can overlap also. The model has many physical parameterizations schemes for cumulus parameterizations, Planetary Boundary Layer Parameterizations, and for radiation parameterization. The technical detail of the modeling system as well as model itself is freely available on internet at http://www.mmm.ucar.edu/mm5/, and hence is not presented here.

1.2 CFD BASED MODEL *fluidyn*-PANEPR

The CFD based model, *fluidyn*–PANEPR, is developed by Fluidyn (http://www.fluidyn.com). PANEPR is specifically developed to study atmospheric dispersion of pollutants over complex topographic conditions. The model was suitably modified to get initial and boundary conditions data from the weather forecast generated by MM5 model. The model was also modified to study atmospheric dispersion of radioactive pollutants. In its basic form, PANEPR uses CFD tools in a finite volume based approach to solve the differential equations governing mass, momentum and energy transfer. The governing equations are written below.

Conservation of species concentration:

$$\frac{\partial(\rho y_m)}{\partial t} + \nabla\cdot(\rho U y_m) = \nabla\cdot(\rho D_m \nabla y_m) + S_m \qquad (2)$$

Continuity equation:

$$\frac{\partial \rho}{\partial t} + \nabla\cdot(\rho U) = S_\rho \qquad (3)$$

Conservation of momentum:

$$\frac{\partial(\rho U)}{\partial t} + \nabla\cdot(\rho U U) = -\nabla P + \nabla\cdot\tau + S_U \qquad (4)$$

Conservation of energy:

$$\left[\frac{\partial(\rho C_p T)}{\partial t} + \nabla\cdot(\rho C_p U T)\right] - \left[\frac{\partial P}{\partial t} + U\cdot\nabla P\right] = -\nabla\cdot q + S_T \qquad (5)$$

Where, ρ : density
- U : velocity vector
- y_m : mass fraction of species m
- T : temperature
- P : pressure
- D_m : effective diffusion coefficient for species m
- τ : viscous stress tensor
- Cp : specific heat at constant pressure
- q : heat flux vector
- S_m : source term for species m
- S_ρ : source term for continuity equation
- S_U : source term for momentum equation
- S_T : source term for temperature equation

The conservation equations of each species are solved with Navier-Stokes equations which regulate the mixed flow, and the energy conservation equations to take into account the heat phenomena. The species transport in PANEPR can also be computed using the Lagrangian particle-puff model, which is available as an alternate dispersion model, in addition to the Eulerian approach (finite-volume method to solve eq. (2) above). The present case study was carried out using Eulerian approach.

The dry deposition flux of a species is evaluated as below:

$$F_{\mathbf{m}}^{\mathbf{d}} = C_{(x,y,0)} V_m^{d} \qquad (6)$$

& the wet deposition is computed using the expression:

$$F_{\mathbf{m}}^{\mathbf{w}} = \Lambda \,.\, \Sigma\, (C_{(k)}.h_k) \qquad (7)$$

where,
- $C_{(x,y,z)}$ = Species Concentration at (x,y,z)
- V_m^{d} = deposition velocity for species m
- Λ = Downwash Coefficient = α . I
- α = Washout Proportionality Constant
- I = Rainfall Rate
- $\Sigma\, (C_{(k)}.h_k)$ = is the integrated concentration over a column (k = 0 to topmost level) at a location (x,y) on ground

PANEPR solves the Reynolds averaged forms of the governing equations (eq. (2) through (5)) for turbulent flow. The Reynolds stresses are modeled using the linear eddy viscosity model (LEVM). Though models like LES score above RANS in modeling re-circulating flows or flows with streamline curvature, it is computationally expensive. This shall be a major limiting factor in the usage of an industrial tool like PANEPR, which is intended to be run on personal computers. Also, the RNG k-eps model used by PANEPR has been found to be reasonably good for flow past obstacles.

The equations describing the large scale evolution of the atmosphere do not take into account the interaction with the surface as the turbulence motion responsible for this interaction is small-scale and totally sub-grid. Hence PBL (Planetary Boundary Layer) phenomena are to be parameterized and PANEPR uses Monin-Obukhov Similarity theory for parameterization of the PBL. It derives the following fundamental physical characteristics of the PBL over the study area:

- Sensible heat flux at ground, Q_h
- Ground roughness factor, z_0
- Monin-Obukhov length, L
- Ground friction velocity, u*
- Temperature scale, θ*

Drag forces on solid walls in a turbulent boundary layer are computed using wall functions which result from the solution of Navier-Stokes equations for a turbulent boundary layer in equilibrium.

The logarithmic law of the wall for momentum is given by:

$$u^+ = \frac{1}{\kappa}\log(Ey^+) \qquad \text{for } y^+ \geq 11.6$$
$$u^+ = y^+ \qquad \text{for } y^+ < 11.6 \qquad (8)$$

where, u^+ = $|\mathbf{U}_p|/u^*$, non-dimensional velocity
y^+ = $\rho u^* y/\mu_l$, non-dimensional wall to cell-centre distance
$|\mathbf{U}_p|$ = fluid velocity parallel and relative to wall
u^* = friction velocity = $C_\mu^{0.25}\sqrt{k}$
y = cell-centre to wall distance
E = a function of wall roughness.
(Jayatilleke's empirical formula is used to evaluate E)

The model can take into account the effects of presence of obstacles such as buildings, and natural features of the landscape like vegetation cover and water bodies, and source effects. PANEPR includes a built-in automatic 3D mesh generator that can create computational finite-volume mesh around obstacles and body-fitting for the terrain undulations. The mesh can be structured (rectangular) or unstructured (triangular) with provisions to cluster the mesh using domain nestings in the regions of specific interest. When used in conjunction with other prognostic wind models such as MM5, it can be used for prognostic analysis of dispersion and hazard also. There are three different turbulence models; K-diffusion, k-l model and k-e model. More technical details can be found in *fluidyn*-PANACHE, user manual, version 4.04, March 2009.

1.3 RADIOLOGICAL DOSE ASSESSMENT MODEL ATTECHED WITH PANEPR

In order to have radiological forecast due to the release of radioactive pollutant, a radiological dose assessment model based on International Atomic Energy Agency (IAEA), Safety Series No. 57, is attached with the PANEPR model. This model assesses radiological doses through various pathways as follows:

The inhalation dose is computed using:

$$D_{INH} = C_{Int}\ (Bq\text{-}s.\ m^{-3})\ .\ B\ (m^{3}.\ s^{-1})\ .\ WCDF\ (Sv.\ Bq^{-1}) \quad (9)$$

where, D_{INH} is the Inhalation dose in Sv, C_{Int} is the time integrated concentration in Bq. s. m^{-3}, B is the Breathing Rate in $m^{3}.\ s^{-1}$, WCDF is the Weighted Committed Dose Factor in Sv. Bq^{-1}

Submersion dose due to β radiation is calculated with:

$$D_{S\beta} = C_{Int}\ (Bq\text{-}s.\ m^{-3})\ .\ WDE\ (Sv.\ Hr^{-1}/Bq.m^{-3})\ /\ 3600\ (s/Hr) \quad (10)$$

here, $D_{S\beta}$ is the β Submersion dose in Sv, WDE (**g_β**) is the Weighted β Dose Equivalent Rate, Sv. Hr^{-1} / Bq . m^{-3}

Submersion dose due to γ radiation is computed using:

$$D_{S\gamma} = C_{Int}\ (Bq\text{-}s.\ m^{-3})\ .\ WDE\ (Sv.\ Hr^{-1}/Bq.m^{-3})\ /\ 3600\ (s/Hr) \quad (11)$$

here also various terms have similar meaning as in the previous case but for γ.

The plume gamma dose rate estimation is relatively more complicated due to the large mean attenuation distance associated with gamma rays and hence it is computed as follows:

$$D_{P\gamma} = 5.0\ E\text{-}04 \iiint E_{\gamma}\ .\ \mu_a\ .\ e^{-\mu R}(1+k\mu R)\ /\ (3600\ .\ 4\pi R^{2})\ .\ C_{Int}\ dxdydz \quad (12)$$

where, $D_P\gamma$ is the plume γ dose in μSv, E_γ is the photon energy, in MeV, μ_a is the energy absorption coefficient in air, m^{-1}, μ is the total energy attenuation coefficient in air, m^{-1}, k is the buildup factor and is defined as $k = (\mu - \mu_a) / \mu_a$.

The ingestion dose is estimated by first estimating the concentration of radionuclide in soil using the following relation:

$$C_{s,i} = [1-\exp(-\lambda^{s}_{Ei}\ .\ t_b)]\ /(P\ .\ \lambda^{s}_{Ei}) \quad (13)$$

where, $C_{s,i}$ is the concentration of radionuclide i in soil (time integrated), Bq . d / kg, λ^{s}_{Ei} is the effective rate constant for reduction of activity concentration of radionuclide i from the root zone of soil, d^{-1} , $\lambda_i + \lambda_s$, where, λ_i is the radioactive decay constant and λ_s is the weathering decay constant in soil, (d^{-1}), t_b is the period of long term deposition for activity in soil, d, and P is the effective surface density for the effective root zone in soil, in kg (dry soil)/m^2.

Using this value $C_{s,i}$ of, the concentration on leafy vegetables is then calculated using:

$$C_{v,i\ veg} = A_{INT}\{\ (R2/Y2)_{veg}\ .\ [1-\exp(-\lambda^{v}_{Ei}\ .\ t_{e2})]\ /\ \lambda^{v}_{Ei} + C_{s,i}\ .\ B_{v2}\ \}\ \exp(-\lambda_i\ .\ t_{h3v}) \quad (14)$$

and then, ingestion dose due to consumption of this vegetables is estimated with:

$$D_{ING1V} = D_I\ .\ C_{v,i\ veg}\ .\ F_{dV} \quad (15)$$

Similarly for the food crop, the estimation of concentration in crop, and then subsequent dose estimation is carried out using:

$$C_{v,i\,crop} = A_{INT} \{ (R2/Y2)_{crop} . [1-\exp(-\lambda^{v}_{Ei} . t_{e2})] / \lambda^{v}_{Ei} + C_{s,i} . B_{v2} \} \exp(-\lambda_{i} . t_{h3c}) \quad (13)$$

$$D_{ING1C} = D_{I} . C_{v,i\,crop} . F_{dC} \quad (16)$$

The total dose due intake of vegetable and food crop then becomes

$$D_{ING1} = D_{ING1V} + D_{ING1C} \quad (17)$$

The various terms used in above equations are as follows:

$C_{v,i\,veg}$ – Fresh matter for leafy vegetables consumed by humans (time integrated), Bq.d / kg.
$C_{v,i\,crop}$ – Fresh matter for food crops consumed by humans (time integrated), Bq . d / kg.
A_{INT} – Integrated Ground Contamination due to Wet and Dry deposition, Bq. m^{-2}.
R2 – Fraction of deposited activity intercepted by food crops as the result of both wet and dry deposition processes.
Y2 – Standing crop biomass of the edible portion of vegetation, kg/m^2.
$(R2/Y2)_{veg}$ – For leafy vegetables.
$(R2/Y2)_{crop}$ – For Food Crops.
λ^{v}_{Ei} – Effective rate constant for reduction of the activity concentration of radionuclide I from crops, = $\lambda_i + \lambda_w$, where, λ_i is the radioactive decay constant and λ_w is the weathering decay constant on vegetation, (d^{-1}).
t_{e2} – time period that crops are exposed to contamination during the growing season, d.
B_{v2} – Concentration factor for uptake of the radionuclide i from soil by edible parts of crops, Bq/g of fresh food per Bq/g of dry soil
t_{h3v} – Holdup time that represents the time interval between harvest and consumption of the leafy vegetables, d.
t_{h3c} – Holdup time that represents the time interval between harvest and consumption of the food crops, d.
D_{ING1V} – Ingestion Dose due to direct consumption of leafy vegetables, Sv.
D_{ING1C} – Ingestion Dose due to direct consumption of food crops, Sv.
D_{ING1} – Total Ingestion Dose due to direct consumption of edible portion of crops, Sv.
D_I – Dose Conversion Factor, Sv . Bq^{-1}.
F_{dV} – Daily intake of Leafy Vegetables by individuals, kg/d.
F_{dC} – Daily intake of Food crops by individuals, kg/d.

The dose due to Grass-Cow-Milk pathway is estimated by first estimating concentration in the fresh forage as well as in the stored feed as follows:

Concentration due to fresh forage:

$$C_{v,i} = A_{INT} \{ (R1/Y1) . [1-\exp(-\lambda^{v}_{Ei} . t_{e1})] / \lambda^{v}_{Ei} + C_{s,i} . B_{v1} \} \exp(-\lambda_{i} . t_{h1}) \quad (18)$$

and concentration due to stored feed:

$$C_{P,i} = A_{INT} \{ (R1/Y1) . [1-\exp(-\lambda^{v}_{Ei} . t_{e1})] / \lambda^{v}_{Ei} + C_{s,i} . B_{v1} \} \exp(-\lambda_{i} . t_{h2}) \quad (19)$$

$$C_{a,i} = f_p f_s C_{v,i} + (1-f_p.f_s) C_{P,i} \quad (20)$$

Then the dose via Grass-Cow-Milk pathway is estimated as:

$$D_{ING2} = D_{I} . C_{a,i} . Q_{f} . F_{m} . M_{k} . \exp(-\lambda_{i} . t_{f}) \quad (21)$$

where

D_{ING2} – Ingestion Dose due to Milk Intake, Sv.
$C_{v,i}$ – Concentration consumed by grazing animals through Fresh forage (time integrated), Bq . d / kg (t_h = 0 days).
$C_{P,i}$ – Concentration consumed by grazing animals through stored feed (time integrated), Bq . d / kg (t_h = 90 days).
Q_f - Amount of dry feed consumed by the animal per day, Kg / d.
M_k – Daily milk intake by individuals, ltr / d.
Fm - Fraction of animal's daily intake of radionuclide that appears in each litre of milk at equilibrium, d. ltr^{-1}.
R1 – Fraction of deposited activity intercepted by forage crops as the result of both wet and dry deposition processes.
Y1 – Standing crop biomass of the edible portion of forage vegetation, kg/m^2.
t_{e1} – time period that forage crops are exposed to contamination during the growing season, d.
B_{vi1} – Concentration factor for uptake of the radionuclide i from soil by edible parts of forage crops, Bq/g of fresh food per Bq/g of dry soil.
t_{h1} – Holdup time that represents the time interval between harvest and consumption of the fresh forage, d, (assumed to be 0 days)
t_{h2} – Holdup time that represents the time interval between harvest and consumption of the stored feed, d, (assumed to be 90 days)
f_p – Fraction of the year that animals consume fresh pasture vegetation (0.4)
f_s – Fraction of daily feed that is fresh forage (0.4)
t_f – Average time of transport of activity from the feed into milk and to the receptor, (default value 4 days)

Similarly the dose due to meat intake is calculated using

$$D_{ING3} = D_I \, . \, C_{a,i} \, . \, Q_f \, . \, F_f \, . \, M_t \, . \, \exp((-\lambda_i \, . \, t_s) \qquad (22)$$

D_{ING3} – Ingestion Dose due to meat intake, Sv
M_t – Daily meat intake by individuals, Kg / d (default value 0.0.274 kg / d)
F_f - Fraction of animal's daily intake of radionuclide that appears in each kg of flesh at equilibrium, d. kg^{-1}
t_s – Average time of transport of activity from the feed to slaughter to consumption (default value 20 days)

The total ingestion dose DING then becomes

$$D_{ING} = D_{ING1} + D_{ING2} + D_{ING3} \qquad (23)$$

The ground shine dose due to β activity deposited on the ground is estimated using following relation:

$$D_{G\beta} = A_{Int}\,(Bq.\ m^{-2})\ .\ g_\beta\,(Sv.\ Hr^{-1}/Bq.m^{-2})\,(1\text{-}e^{-\lambda.texp}) / \lambda\,(s^{-1})\ .\ 3600\,(s/Hr) \qquad (24)$$

here, $D_{G\beta}$ –DOSE Due to Ground Contamination, Sv
A_{INT} – Integrated Ground Contamination due to Wet and Dry deposition, Bq. m^{-2}
g_β – β Dose Conversion Factor for Ground Contamination, $Sv.Hr^{-1}/ Bq.m^{-2}$
λ – Radioactive decay constant, s^{-1}
t_{exp} – Period of long term exposure to the deposited activity, s

and similarly, the ground shine dose due γ activity deposited on the ground is:

$$D_{G\gamma} = A_{Int}\,(Bq.\ m^{-2})\ .\ g_\gamma\,(Sv.\ Hr^{-1}/Bq.m^{-2})\,(1\text{-}e^{-\lambda.texp}) / \lambda\,(s^{-1})\ .\ 3600\,(s/Hr) \qquad (25)$$

$D_{G\gamma}$ –DOSE Due to Ground Contamination, Sv
A_{INT} – Integrated Ground Contamination due to Wet and Dry deposition, Bq. m^{-2}
g_{γ} – γ Dose Conversion Factor for Ground Contamination, $Sv.Hr^{-1}/Bq.m^{-2}$
λ – Radioactive decay constant, s^{-1}
t_{exp} – Period of long term exposure to the deposited activity, s

the total dose to the individual then becomes:

$$\text{TOTAL DOSE (Sv)} = D_{INH} + D_{S\beta} + \{ D_{S\gamma} \text{ or } D_{P\gamma} \} + D_{ING} + D_{G\beta} + D_{G\gamma} \quad (26)$$

2. HYPOTHETICAL CASE STUDY

In order to check the performance of combined MM5-PANEPR-Dose Module system, a hypothetical case study was carried out. In this, MM5 model was run with global forecasted meteorological data obtained from National Centre for Medium Range Weather Forecast (NCMRWF), New Delhi, using T-80 model. A nested run for 24 hours was carried out for September 27, 2004, with 3-domains running simultaneously with grid resolution of 90km, 30km, and 10km. The MM5 forecasted meteorological field for the innermost domain (150km x 150km, 10km resolution) was used for running PANEPR model at grid resolution of 5 km. The grid resolution of 5km was used to reduce computational time, in principle; there is no restriction on grid resolution in PANEPR model. A hypothetical release point at the height of 145m was assumed at the centre of the domain with a continuous and constant release rate of 1.0E+10 Bq/s of Cs-137 for a period of 24 hrs. PANEPR generated instantaneous concentration, time integrated concentration, deposited activity, and radiological doses at the interval of 1 hour, however, for testing purposes, the results were plotted at the interval of 6 hours, starting from the 06 GMT on September 27, 2004.

In the coupled MM5-PANEPR modeling system, PANEPR extracts static data on terrain elevation from the MM5 model output, it also extracts time varying data on u, v components in 3 dimensional domain, similarly ambient temperature in 3-dimensional domain and 2 dimensional data on ground temperature, rainfall rate, sensible heat flux and mixing height information. These data were used to initialize PAEPR model at an interval of 1 hour.

3. RESULTS AND DISCUSSION

The results are generated at 06 hours interval and from these; typical results at 12 GMT of the hypothetical case study mentioned in the previous section are given in Figure-1(a) through (c). The results were checked for the consistency of plume behavior with respect to the wind field generated by MM5 model as well as with respect to the PAEPR generated wind field. It was found that the wind field generated by both the models agreed well with each other, however, PANEPR model generated wind field at finer resolution as compared to the MM5. As mentioned earlier, PANEPR could generate wind filed even at a grid resolution of meter, provided terrain elevation as well as the information on building structure etc. is provided at that resolution, and enough computational power is made available. In order to check the reliability of the coupled system, the model generated results on instantaneous concentration, time integrated concentration and plume gamma dose were compared with the same generated using MM5-RIMPUFF modeling system. MM5-RIMPUFF coupling was carried out in the Environmental Assessment Division of Bhabha Atomic Research Centre. RIMPUFF is a Gaussian Puff based atmospheric dispersion model for radioactive pollutants developed by Riso National Laboratory, Denmark (Thykier et. al., 2004). The RIMPUFF model has facility to estimate gamma dose rate and hence the same obtained with MM5-PANEPR were compared with the MM5-RIMPUFF modeling system. As can be seen from the Fig. 1, the flow field and contours for instantaneous concentrations were fairly comparable. However, contours of time integration concentration and plume gamma dose were only consistent at the lower range values. Analysis of difference in results between the two models can be carried out only on the basis of some experimental data which, atleast for radiation dose values, is non-existing.

4. CONCLUSION

It was found that the coupling of Numerical Weather Prediction Model, such as MM5, with a CFD based model, such as PANEPR, could generate useful results that can strengthen the emergency preparedness of Nuclear Power Plant Site. Since the coupled system can operate in prognostic mode, the prognosis of meteorological as well as radiological conditions can be extremely useful in planning the counter measures in case of accidental releases. Another advantage of such system is incorporation of terrain elevation, information on building structure at very high resolution in the estimation of atmospheric dispersion of pollutant, which otherwise is not possible in meteorological models due to relatively poorer grid resolution.

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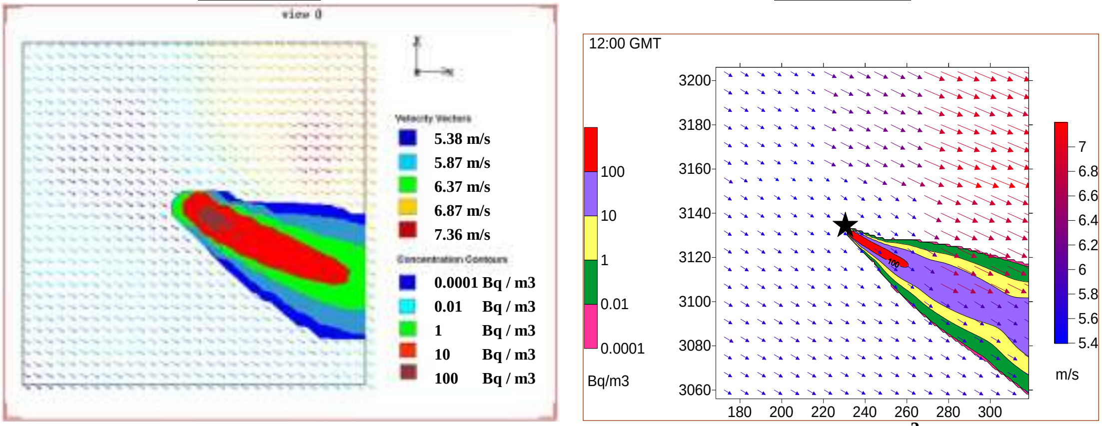
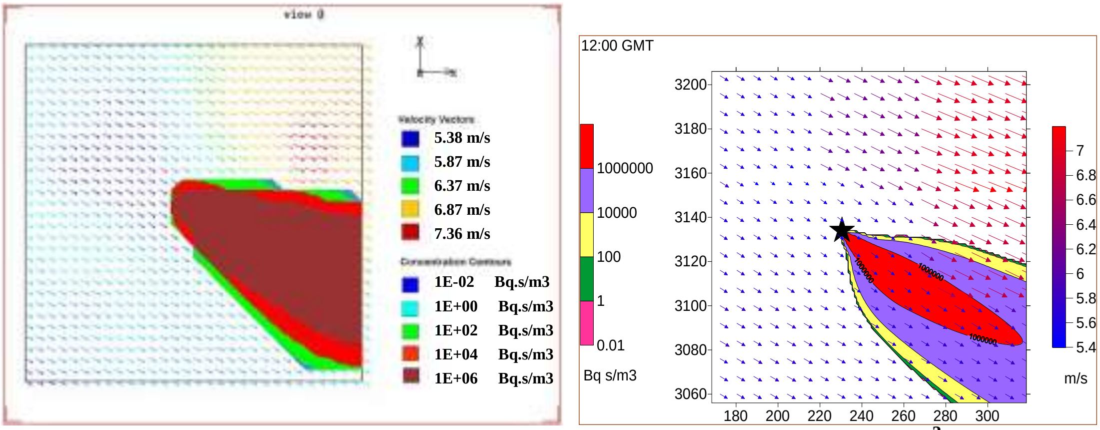
Thykier-Nielsen, S., Deme, S., and Mikkelsen, T., "RIMPUFF Atmospheric Dispersion Module", Riso National Laboratory, Denmark, (2004).

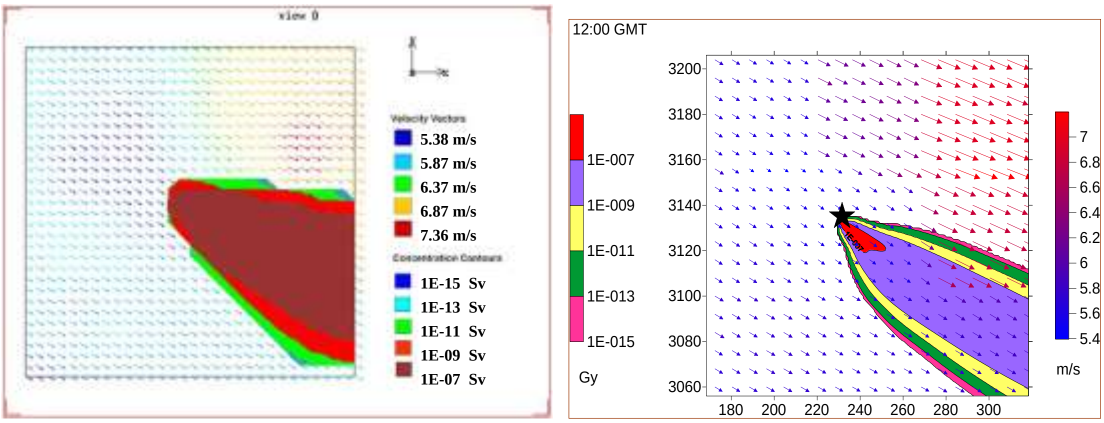
PANEPR RIMPUFF



(a) Instantaneous concentration at 12:00 GMT, Bq/m^3



(b) Time integrated concentration at 12:00 GMT, Bq.s/m^3



(c) Plume gamma dose at 12:00 GMT, Sv

Figure-1: Comparative results of MM5-PANEPR-Dose Module coupled system against RIMPUFF at 12:00 GMT