Dispersion of radioactive aerosol past obstacles

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Vreman (2004) subgrid model

The modelled subgrid stresses τ_{ij} are determined the Vreman model (Vreman, 2004). The model is guaranteed to give $\nu_t = 0$ in for the laminar flow. A dynamic version exists, but is not utilized here.

$$\nu_t = c\sqrt{\frac{B_\beta}{\alpha_{ij}\alpha_{ij}}}$$

where

$$\alpha_{ij} = \frac{\partial \bar{u}_j}{\partial x_i}$$

$$\beta_{ij} = \sum_m \Delta_m^2 \alpha_{mi}\alpha_{mj}$$

$$B_\beta = \beta_{11}\beta_{22} - \beta_{12}^2 + \beta_{22}\beta_{33} - \beta_{23}^2 + $$
$$+ \beta_{33}\beta_{11} - \beta_{31}^2$$

Generation of turbulent inflow

The inflow boundary conditions must incorporate turbulent fluctuations and provide them with correct correlations and variances according to prescribed profiles of mean wind and turbulent stresses. We used a method based on random number generation by Klein, Sadiki and Janicka (2003) in a more effective version by Xie and Castro (2008). Random 2D fields are first filtered to get desired autocorelation and then transformed for correct variances and correlations between components.

$$\psi_i^* = \psi_i^n \exp\left(\frac{-\pi\Delta t}{2T}\right) +$$
$$+ \psi_i^{n+1}\left[1 - \exp\left(\frac{-\pi\Delta t}{2T}\right)\right]^{0.5}$$
$$u_i = \bar{u}_i + a_{ij}\psi_j^*,$$

where a_{ij} is a function of Reynolds tensor, ψ_i spatially filtered random fields and T turbulent time scale.

Other

- •Projection method for incompressible flow with Runge-Kutta timestepping
- •Space discretization by the finite volume method and central diferences
- •Wall model on solid walls uses wall function with log profile

Dispersion experiments performed by the National Radiation Protection Institute

- •experiment with an explosive device used to disperse radioactive matter (Prouza et al., 2010)
- •immitation of a "dirty bomb" attack
- •approximately 1 GBq of ^{99}Tc in the form of liquid solution released
- •We assume, that al of the activity is after the explosion in the form of aerosol with uniform initial concentration in a box 7 × 7 × 12 m.
- •2 obstacles placed downwind from the, the main one is a bus covered by canvas.
- •Measured quantities include: contamination of deposition on a 5m grid, time history of PM10 concentration in 3 places along centerline and the particle size distribution
- •Very low wind speed ≈ 0.5 m/s caused high uncertainty in the wind measurement.

Results

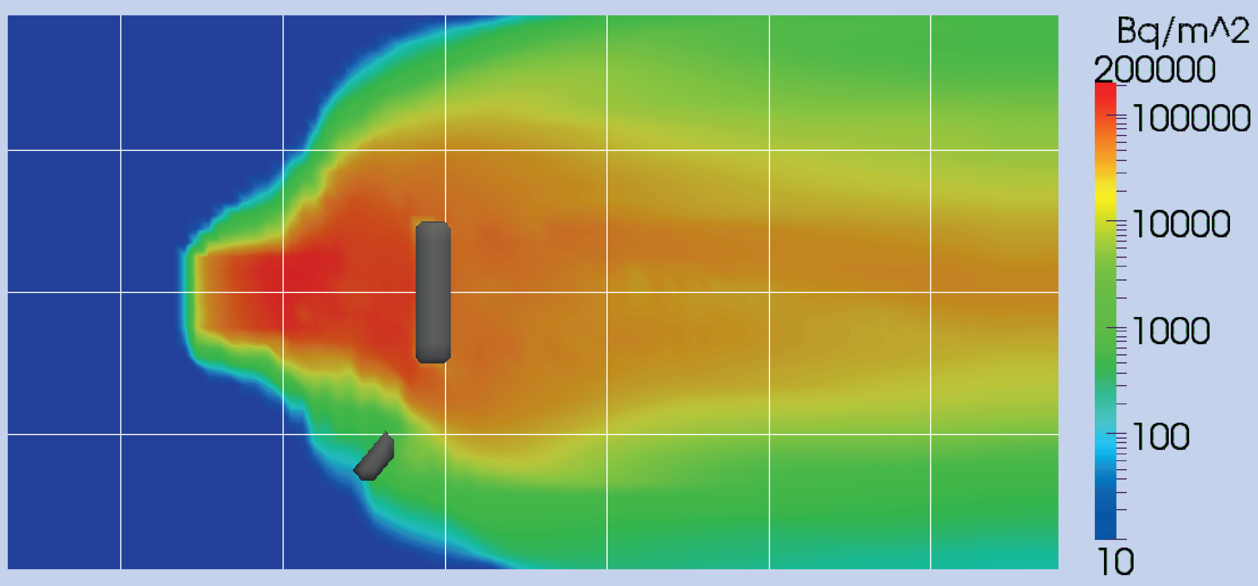

Fig. 1. Deposition of activity on the ground. The order of magnitude of maxima is correct, but the significantly contaminated area is much larger, then measured. Grid lines every 10 m.

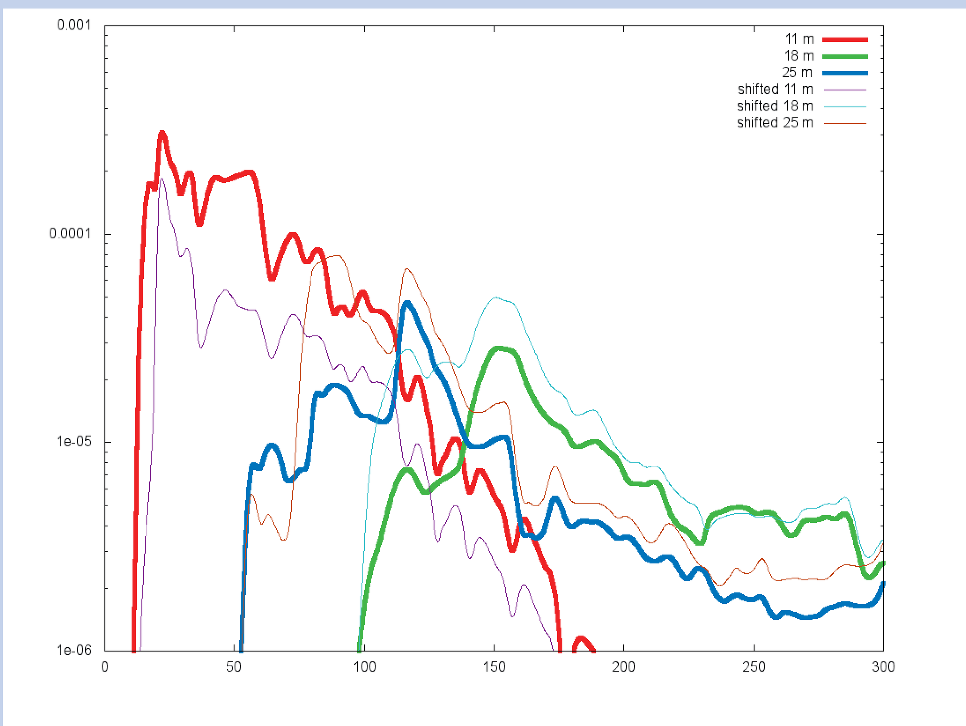

Fig. 2. Time history of activity in GBq/m^3 in three positions aleng the centerline, where aerosol detectors were placed. 11m is just in front of the bus and 18 m is behind it. The order of the first detected signal in measurements was 18m, 11 m and 25 m, contrary to our simulation.

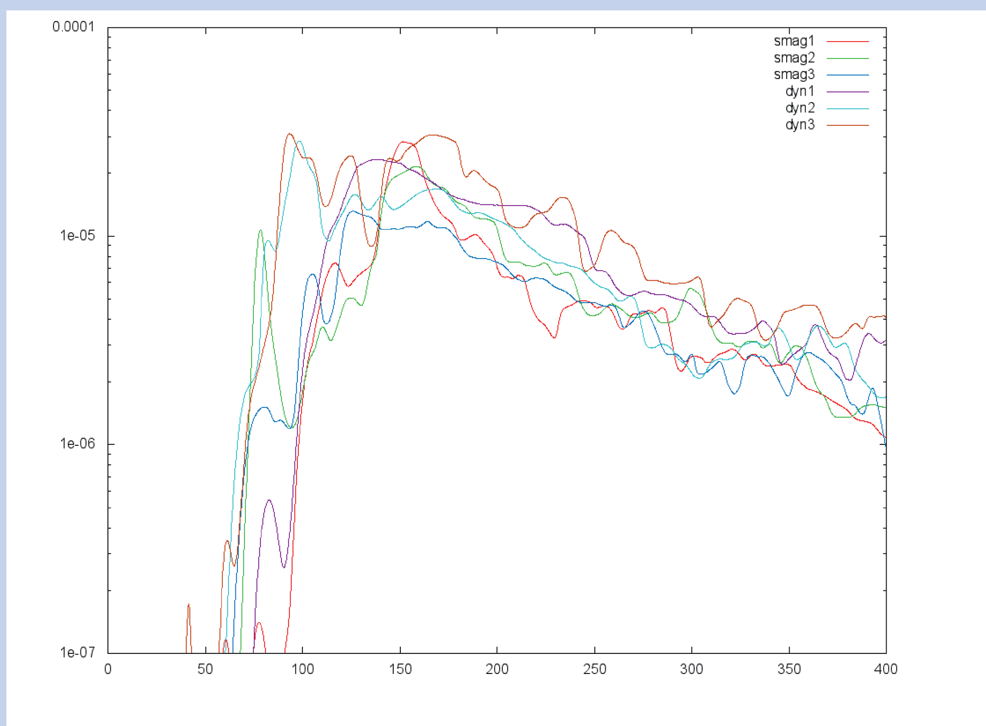

Fig. 3. Ensemble of time histories of activity in GBq/m^3 in the detector behind the bus (18 m from epicenter).

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