Short scale scenario

Vladimír Fuka, Josef Brechler

Dept. of Meteorology and Environment Protection, Charles University in Prague

Wien, 24.–28. January 2011

Introduction

- Our model CLMM is a general-purpose high resolution code for atmodpheric CFD..
- It uses a Large Eddy Simulation framework, which requires high resolution and has large demands on computational time, but enables very accurate flow field computations.
- It's primary purpose are studies with lower uncertainties in inputs, than this one. (Faster less complex code would suffice)
- In principle it is able to cope with stability, but in a different way, than the simple stability categories and it could not be used for this study.

Introduction

- Validation using Thopson's wind tunnel data (Atm. Env. 1993) of atmospheric dispersion in the presence of a building in many configurations.
- Differences of simulation and measurement were almost always less then a factor of 3 and mostly less than a factor of 2 (still not ideal, the work continues).

Large Eddy Simulation

- Filtered momentum equations

$$\frac{\partial \overline{u_i}}{\partial t} + \frac{\partial \overline{u}_i \overline{u}_j}{\partial x_j} = -\frac{\partial \overline{p}}{\partial x_i} + \frac{\partial 2\nu \overline{S}_{ij}}{\partial x_j} + \frac{\partial \tau_{ij}}{\partial x_j} \tag{1}$$

$$\tau_{ij} = \overline{u}_i \overline{u}_j - \overline{u_i u_j} \tag{2}$$

- Continuity equation

$$\frac{\partial \overline{u}_i}{\partial x_i} = 0 \tag{3}$$

Other numerical methods

Projection (fractional step) method with a 3rd order Runge-Kutta method for time discretization.

Finite volume spatial discretization on a staggered grid.

Concentration field are treated in Eulerian manner, i.e. average concentrations in fixed grid boxes.

Dry deposition

Dry deposition

For dry deposition of particles we employ a semi-empirical scheme by Kharchenko (1997).

$$v_{\mathrm{d}} = f(\nu, d, D, z_0, u_*, \tau^+) \tag{4}$$

where (5)

$$d = \text{particle diameter} \tag{6}$$

$$D = \text{coefficient of Brownian diffusion} \tag{7}$$

$$\tau^+ = \frac{u_{\mathrm{sed}}}{g}\frac{u_*^2}{\nu} \tag{8}$$

We found too late, that the v_{d} for larger particles is much higher, than suggested by Kasper and Govert.

Turbulent inflow

- One of difficult problems in LES is imposing inflow boundary conditions, that are turbulent and as realistic, as possible.
- We generate the incoming field using random numbers.
- The generated flow has to have propper length scale and spectrum to contain the lower wavenumbers.
- Also correct correlation between velocity components is important.

Turbulent inflow

- We use the Reynolds tensor components reported in literature for neutral boundary layer scaled by the friction velocity (i.e. σ_u/u_*, σ_v/u_*, σ_w/u_*).
- The mean wind and stress profiles can be prescribed by the user.

Parameters I.

- The grid is always uniform, although generally the code is capable of nonuniform grid, some of the methods can be used only for uniform grid (for now at least).
- Two domains for computation: up to 50 m and up to 2000 m (both with some additional buffer zone) These were 2 separate computations.
- The wind velocities and directions were chosen by time averaging (3.8 m/s, 0.77 m/s, 2.3 m/s, 0.4 m/s)

Parameters II.

- We used 4 separate classes of particle sizes that were treated independently each with fixed diameter and initial percentage.

0.2µm	39.6%
1µm	11.8%
8µm	37.8%
20µm	10.8%

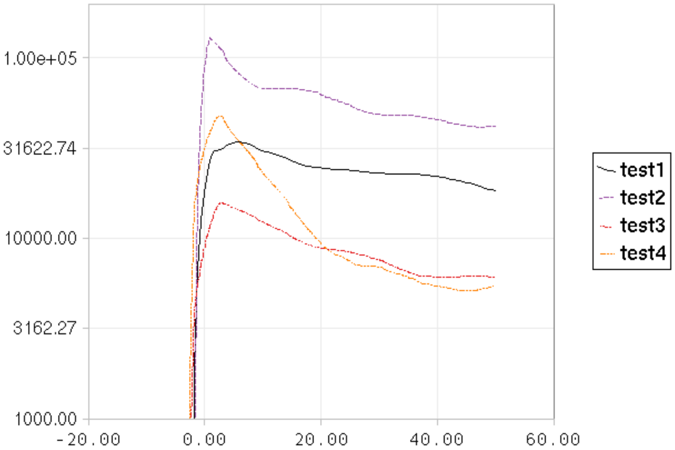
Parameters III.

- The incoming flow had logaritmic profile. The turbulent stresses were computed using roughness length 10 cm.
- The roughness length for the ground surface was 3 mm.
- The initial cloud in the form of cylinder as we agreed, with the vertical distribution according to HOTSPOT.

Results

- The main feature that is common to all our computations is a much weaker decay of deposite activity with distance than measured (in other scenarios with released data).
- We tried to play with the initial aerosol distribution, but couldn't find anything clearly better.
- Also the 2 km run was at a rather coarse resolution of 12.5 m.

Deposition at the plume centerline



Percentiles of contaminated area

The percentiles of the contaminated area (only up to 2 km):

	test 1	test 2	test 3	test 4
50 %	4 ha	2.2 ha	4.8 ha	3.36 ha
75 %	12.6 ha	8.4 ha	14.2 ha	12.5 ha
95 %	29.5 ha	24.9 ha	30.6 ha	30.9 ha

We did not not compute the γ dose rates.