5.26 A NEW OPERATIONAL APPROACH TO DEAL WITH DISPERSION AROUND OBSTACLES: THE MSS (MICRO SWIFT SPRAY) SOFTWARE SUITE

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INTRODUCTION

Dispersion around obstacles traditionally needs a CFD model well adapted for the PBL and heavy CPU resources. This approach is not easily used in two important applications: (1) emergency response or preparedness, (2) long term impact around a source near the ground.

In this paper, a new approach tagged as " 90% of the solution for about 10% of the CPU" is described. This method allows an exact representation of buildings directly generated by a GIS (as .shp files). A first guess of the 3D mean flow is computed using all available and relevant meteorological data (inside or outside the target domain). This field is then modified using analytical corrections due to the obstacles (*Kaplan and Dinar*, 1996). At last, the mass consistent field is deduced considering the topography and the filled (or porous) cells representing the buildings. Turbulence is diagnostically deduced considering the distance to the nearest obstacle as a mixing length. This micro-scale quick solution to the flow problem is called Micro SWIFT.

Dispersion is simulated through a modified version of SPRAY, a Monte-Carlo Lagrangian dispersion code (*Tinarelli et al*., 1994), where particles are reflected by the ground and by obstacles, and discretisation time steps are set up in order to better follow the large gradients of meteorological fields induced by obstacles. Different comparisons both with other approaches (such as CFD and wind tunnel) and field data have been obtained. The implementation of MSS in operational tools such as the new version of HPAC (US-DOD) has now been completed successfully.

In particular, some street canyon field data have been collected in Northern Italy, with several different street configurations, representing typical situations in terms of both geometry and traffic emissions. Some numerical experiments are under construction to reproduce these situations and preliminary results will be briefly shown here.

MSS DESCRIPTION

Micro SWIFT

As described above, SWIFT is an analytically modified mass consistent interpolator over complex terrain. Given a topography, meteorological data and buildings, a mass consistent 3D wind field is generated by following the steps below:

- according to meteorological data, a first guess of the mean flow is computed through customisable interpolation
- this first guess is then modified to take into account obstacles by creating analytical zones where the flow is modified according to buildings, these being isolated or not (see *Röckle R*., 1990 or *Kaplan H. and Dinar N.* , 1996). An example of zones attached to a rectangular obstacle is shown on figure 1.

- finally, this flow is adjusted in order to satisfy the continuity equation and impermeability on the ground and on the building walls

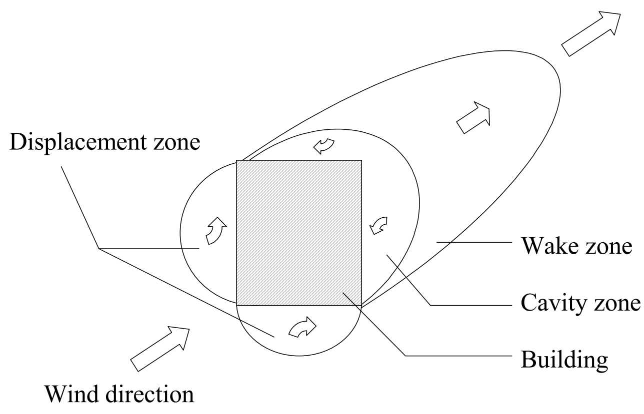

Figure 1. Top view of an isolated building and its attached zones

Micro SWIFT is also able to derive a diagnostic turbulence (namely the diffusive coefficients and the turbulent kinetic energy dissipation rate) to be used inside Micro SPRAY. This turbulence is deduced considering the distance to the nearest obstacle as a mixing length and using the value of the wind field local shear.

Micro SPRAY

Micro SPRAY is a Lagrangian particle dispersion model directly derived from the SPRAY code (*Tinarelli et al..,* 1994, 1998), able to take into account the presence of obstacles. The dispersion of an airborne pollutant is simulated following the movement of a large number of fictitious particles, each representing a part of the emitted mass from sources of general shapes. This movement is obtained applying a simple equation of motion where the particle velocity is split into two components: a mean one, or “transport-component”, which is defined by the local wind reconstructed by Micro SWIFT, and a stochastic one, simulating the dispersion and reproducing the atmospheric turbulence. The stochastic component of the particle motion is obtained applying the scheme developed by Thomson (*Thomson*, 1987).

$$\frac{dX_p(t)}{dt} = U_p(t) \qquad dU_p(t) = a(X,U)\,dt + \sqrt{B_0(X)dt}\,d\mu_p \quad (1)$$

where **Xp(t)** and **Up(t)** represent the 3D particle position and velocity vectors defined on a fixed Cartesian reference frame. a and B_0 are determined to fulfill the ‘Well-mixed’ condition, by the turbulent dispersion coefficients K and the dissipation rate ε given by Micro SWIFT, dμ is a stochastic standardized Gaussian term (zero mean and unit variance). Obstacles or buildings are taken into account by setting impermeable some of the cells of the terrain following grid where meteorological fields are defined.

PRELIMINARY VALIDATION CASES

Preliminary validation has been obtained for different sets of data, ranging from CFD and wind tunnel to real field experiments

U-shape building

The data of the U-shape isolated building are wind tunnel data obtained at the Institute of Hydrology and Water Resources (University of Karlsruhe, Germany). Runs were also performed using a German CFD code named MISKAM and a model similar to the MSS approach, called ABC. A tracer gas was released from 3 different locations and for different wind directions (see figure 2). Concentration measurements were made in a plane 40m (20cm in the wind tunnel) downwind of the source. Table 1 shows the ratio between the measured/computed maximum in this plane for MISKAM, ABC and MSS.

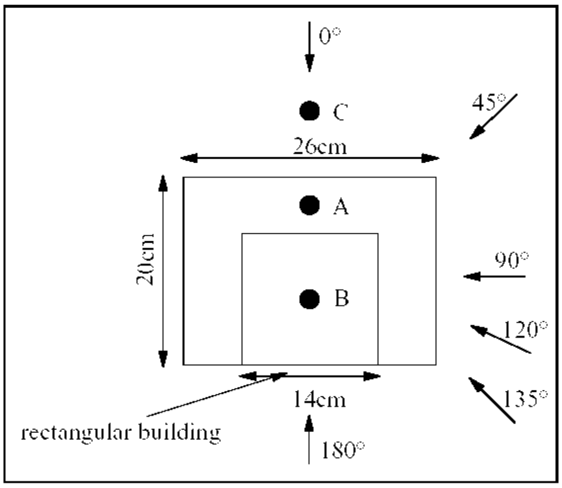

Figure 2. Wind directions and release point locations for the U-shape experiment.

Table 1. Ratio between the computed (cn) and measured (ce) concentration maximum 40m downwind of the source for ABC, MISKAM and MSS models.

cn/ce	ABC	MISKAM	MSS
[1/10,1/5]	1	0	1
[1/5,1/2]	5	8	1
[1/2,2]	4	4	9
[2,5]	2	0	0
[5,10]	0	0	1
number of values	12	12	12

URBAN 2000

URBAN 2000 is a meteorological and tracer field experiment funded by the US-DOE to study the urban environment and ultimately its effect on atmospheric dispersion that was conducted in Salt Lake City in October 2000. Experiments were performed to investigate transport and diffusion around a single downtown building, within and through the downtown area and into the greater Salt Lake City urban area. For our purposes, we considered the urban domain (roughly a 400m*400m domain around the release point that can be seen in the top view of Figure 3). We simulated 30mn of a 1h SF6 release and compared this to sonic anemometers measurements for the wind and sample bags for the concentration.

It is worth noting that the solution creates realistic recirculation which generate upwind dispersion of the material.

Bologna

A field experiment has been conducted in the centre of Bologna (historical middle age town located in northern Italy) in order to collect information about meteorology and road emissions to reconstruct the ground pollution levels, in particular for PM10 and PM2.5. The region under consideration covers an area of about 500x500 m^2 (Piazza Maggiore) around the main cathedral, and is characterized by a composite urban environment, with deep canyons and a complex network of both narrow and wide roads. Normal vehicular traffic is possible only on a part of these roads while in some of the others a limited traffic level is admitted or totally forbidden. Standard meteorological (cup anemometers and thermometers) and more sophisticated (sonic anemometers) measurements were collected in order to reconstruct both the mean flow and the turbulence. PM10 and PM2.5 concentrations and traffic levels, characterized in terms of both number and type of vehicles, are measured at points where different traffic regimes are admitted. MSS is applied in these conditions in order to reconstruct both the local flow and the pollution levels on the entire domain considered. This work is still in progress. Preliminary simulations with Micro SWIFT have been produced in order to verify the complexity of the mean fields produced. In figure 4 a sample wind field close to the ground generated by the code is represented.

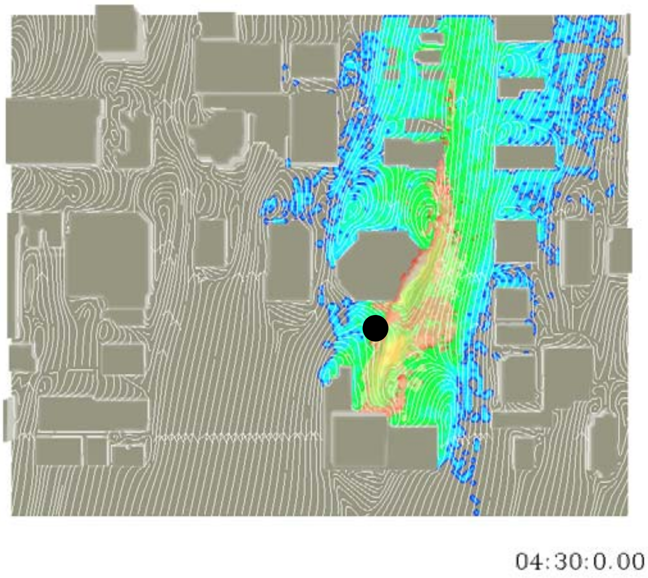

Figure 3. Streamlines & GLC field generated 30 mn after release. Source=dot

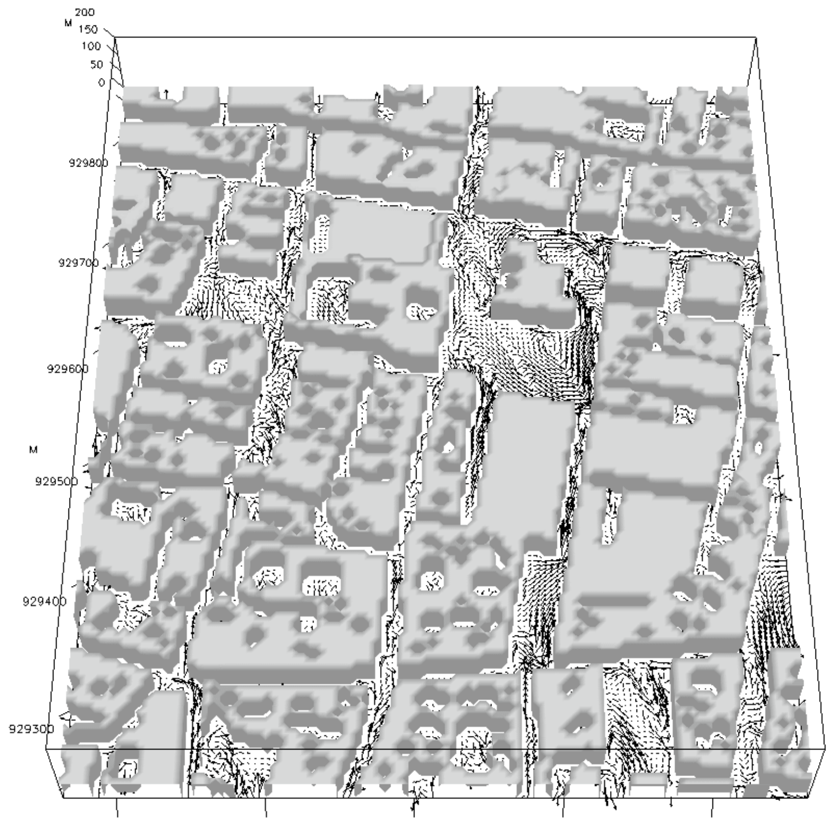

Figure 4. Example of wind field simulation in the centre of Bologna.

The horizontal grid step adopted in this case is 4m, while the vertical extension of the computational domain is 200m. The complexity of the generated fields is quite straightforward, see the presence of many low wind speed sub-regions where the direction is almost random, alternated by regions where channelling effects tend to reinforce the flow. Simulations with the Micro SPRAY dispersion code are under development, in order to reconstruct the impact due to the different road traffic levels present in the zone.

CONCLUSION

The validations presented in this document show good agreement between measured and computed data, especially when considering the CPU cost of a typical MSS computation, the 30mn long urban 2000 simulation taking less than 5mn on a PIV laptop. More validation still need to and will be performed (Bologna test case for instance) in the near future.

ACKNOWLEDGMENTS

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REFERENCES

Allwine K.J., Shinn J.H., Streit G.E., Clawson K.L. and Brown M., **2002:** Overview of Urban 2000. *Bulletin of the American Meteorological Society,* **83 (4)**, 521 – 536.

Hosker R.P., **1984:** Flow and diffusion near obstacles. *Atmospheric Science and Power Production,* DOE/TIC-27601.

Kaplan H. and Dinard N., **1996:** A Lagrangian dispersion model for calculating concentration distribution within a built-up domain. *Atmospheric Environment,* **30 (24)**, 4197 – 4207.

Kastner-Klein P., Plate E. and Fedorovich E.., **1997 :** Gaseous pollutant dispersion around urban-canopy elements: wind tunnel case studies. *Int. J. Environment and Pollution,* **8 (3-6)**, 727 – 737.

Röckle R.., **1990:** Bestimmung der Strömungsverhältnisse im Bereich komplexer Bebauungsstrukturen. *PhD. thesis,* Darmstadt, Germany.

Rodean H.C., **1996:** Stochastic Lagrangian models of turbulent diffusion. *American Meteorological Society Meteorological Monographs,* **26 (48)**.

Thomson D.J. **1987:** Criteria for the selection of stochastic models of particle trajectories in turbulent flows. *J. Fluid Mech.,* **180**, **529-556**.

Tinarelli G., Anfossi D., Brusasca G., Ferrero E., Giostra U., Morselli M.G., Moussafir J., Tampieri F., Trombetti F., **1994:** Lagrangian particle simulation of tracer dispersion in the lee of a schematic two-dimensional hill", *Journal of Applied Meteorology*, **33**, **N. 6**, **744-756**.

Tinarelli G., Anfossi D., Bider M., Ferrero E., Trini Castelli S, **1998:** A new high performance version of the Lagrangian particle dispersion model SPRAY, some case studies, *Proceedings of the 23rd CCMS-NATO meeting, Varna, 28 September - 2 October 1998*, **499-507**, Kluwer Academic.

Williams M.D., Brown M.J and Pardyjak E.M.., **2002 :** Development of a dispersion model for flow around buildings. *Fourth Symposium on the Urban Environment,* Norfolk.