P6.1 INFLUENCE OF A SMALL-SCALE TOPOGRAPHY ON THE DYNAMICS OF ATMOSPHERIC BOUNDARY LAYER FLOWS USING GRID-NESTING APPROACH

Thibauld Pénelon*, Isabelle Calmet and Patrice G. Mestayer
Laboratoire de Mécanique des Fluides, École Centrale de Nantes, Nantes, France

1. INTRODUCTION

Micro-meteorological simulations with high-resolution near the ground are of great interest to study pollutant dispersion and to get accurate information on the lower atmosphere dynamic and thermal fields necessary for predicting long-range noise propagation (typically between the ground and 50 meters). The present study is in line with the second topic: it aims at estimating the terrain-influenced meteorology. The small-scale complex terrain of St-Berthevin (Mayenne, France) –a 50 meters deep valley– has been chosen for this numerical investigation, partly due to the availability of wind and acoustic fields measurements recorded during a two-week experimental campaign.

2. NUMERICAL METHOD

Accounting for the influence of large-scale meteorological fields on smaller ones requires the extension of the computational domain quite far from the area of interest that must be accurately described by the grid. Using a fine mesh over the whole domain is presently not feasible due to computer performances. To overcome this problem, a currently used method is the grid-nesting approach. The finite-difference non-hydrostatic compressible 3D atmospheric model SUBMESO (Anquetin *et al.*, 1998) and a technical module (Blayo & Debreu, 1999) able to manage the Adaptive Mesh-Refinement (AMR) method developed by Berger & Oliger (1984) have been coupled together. The grid-nesting module was developed to be adaptable to any finite-difference oceanographic or atmospheric model, with minimum changes in the single-grid model. In order to focus on an *a priori* defined limited-range area, the adaptive aspect of the method has been left aside while our particular effort was concerned with the improvement of the grid-nesting boundary conditions; those were initially restricted to the interpolation of coarse-grid fields at the fine grid boundary. Among all the boundary conditions suggested in the literature, the most effective one to avoid the reflection of numerical waves at an outflow boundary seems to be the radiative condition proposed by Carpenter (1982) applied to all the prognostic variables, except the pressure for which Dirichlet conditions are less disturbing. The inflow boundaries are treated with the simple Dirichlet conditions. The method, used in one-way interaction, was first validated (Pénelon, 2002) against the case of a stably stratified atmospheric flow over a 2D 1-m-high hill, which provides a direct comparison with analytic solution, and against the 3D case of neutral flow over flat terrain where streaky structures are observed.

**Corresponding author address*: Thibauld Pénelon, LMF UMR 6598 CNRS-ECN, 44321 NANTES Cedex 03, France; e-mail: Thibauld.Penelon@ec-nantes.fr

3. SIMULATIONS OVER COMPLEX TERRAIN

The numerical method is applied to the large-eddy simulations of the atmospheric flow above the real topography of St-Berthevin (Fig.1) crossed from north-west to south-east by the valley of the river Vicoin. The large domain (8 km $\times$ 6 km) is discretized with an horizontal mesh size of 150 m. The nested grid (2 km $\times$ 2 km), centered on the valley, has a 50 m mesh size. Both coarse- and fine-mesh grids are stretched on the vertical, with a minimum mesh size of 10 m near the ground and a mean size of 250 m. The domain is 7 km high.

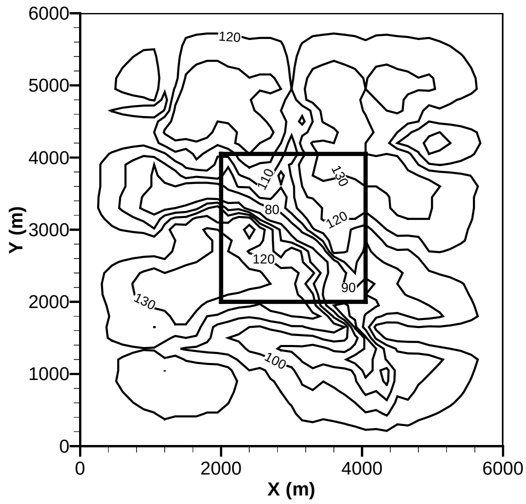

Fig. 1 Topography of St-Berthevin (10 m contour step). The square shows the nested domain.

In order to estimate the accuracy of numerical results at several locations in the valley where instrumented masts were installed, three meteorological situations were chosen among the conditions measured upstream from the region of interest: a stably stratified flow (Q_s = -0.012 K.m.s^{-1}) with a weak wind blowing from west (u*= 0.21 m.s^{-1} corresponding to U = 2.2 m.s^{-1} at 6 m above the ground), and two convective flows with a north-westerly strong wind and a south-westerly moderate wind, respectively. Small-scale topography is much more influencing the flow for stable than for unstable stratification. Thus, we focus here on the results obtained in the first case that is also known to be the most favourable to long-range noise propagation. Only the results from the stable case in the nested domain are shown.

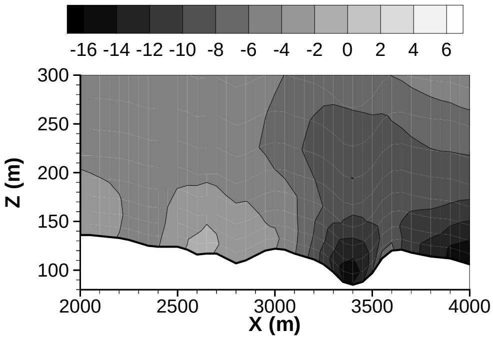

Fig. 2 Wind direction with respect to x-axis (in degrees) in a vertical cross-section y = 2700 m

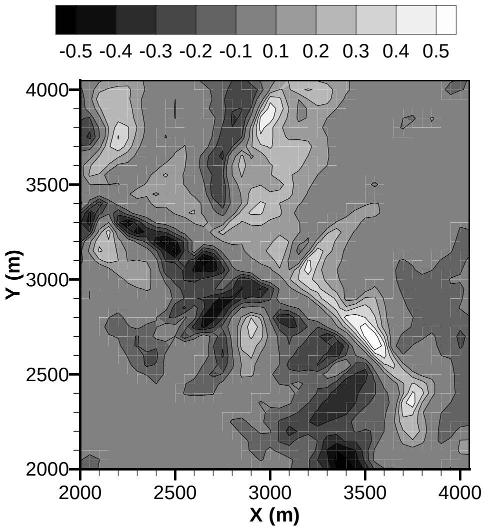

Fig. 3 Mean vertical velocity at 5 m above the ground

Figure 2 clearly shows the channelling effect induced by the small valley. At the bottom of the valley the wind is submitted to a rotation of about -10° from its original direction, which is -4° with respect to the west-east axis. The same amplitude of rotation is observed in the experimental data. At the same location the wind rotation on the coarse grid (not shown) is less accurate since a global deviation is observed between x = 3200 m and x = 4000 m. The vertical velocity field (Fig. 3) underscores the strong correlation between flow and topography under stable conditions. In the unstable cases, convective phenomena break this layout. Deceleration and acceleration effects induced by hollows and crests are well apparent in Figure 4. The smaller transverse valley in the northern part of the domain induces a stronger deceleration than the main valley, which appears to channel the flow rather than to reduce its velocity.

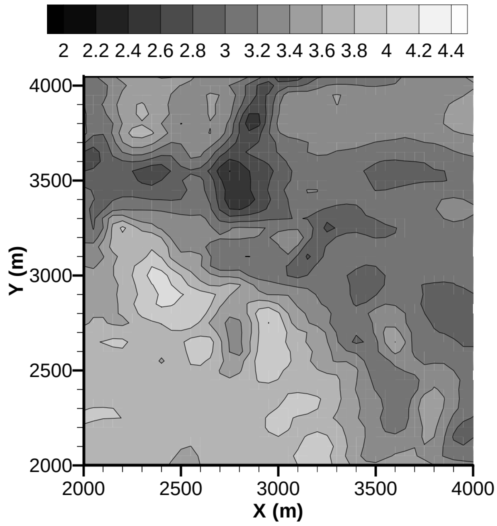

Fig. 4 Mean horizontal wind at 5 m above the ground

4. CONCLUSIONS

This study demonstrates the efficiency of the grid-nesting approach to obtain accurate information on the small-scale flow behavior accounting for large-scale conditions. Numerical predictions seem in quite good agreement with measurements but further analysis is still needed.

Ackowledgments. This work was supported by *Laboratoire Central des Ponts et Chaussées (EGU07).*

5. REFERENCES

Anquetin, S., J. P. Chollet, A. Coppalle, P. Mestayer & J. F. Sini, 1998 : The Urban Atmosphere Model SUBMESO, Contribution to the sub-project SATURN. *EUROTRAC Symposium '98*, Garmisch-Partenkirchen 23-27 March 1998. proceed. P.M. Borrel & P. Borrel eds., WIT Press, Boston, Southampton, **2**, 750-757.

Berger, M. & J. Oliger, 1984: Adaptive mesh refinement for hyperbolic partial differential equations. *J. Comp. Phys.*, **53**, 484-512.

Blayo, E. & L. Debreu, 1999: Adaptive mesh refinement for finite-difference ocean models: first experiments. *J. Phys. Ocean.*, **29** (6), 1239-1250.

Carpenter, K. M., 1982: Note on the paper "Radiation conditions for the lateral boundaries of limited-area numerical models" by M.J. Miller and A.J. Thorpe (Q. J., 107, 615-628). *Q. J. R. Met. Soc.*, **108**, 717-719.

Pénelon, T., 2002: Simulations micrométéorologiques sur site complexe avec le modèle SUBMESO. Ph.D Thesis, Ecole Centrale de Nantes.