6.02 SIMULATION AND COMPARISON OF MEAN FLOW, TURBULENCE AND DISPERSION IN COMPLEX TERRAIN

S.Alessandrini[1], E.Ferrero[2,3], S. Trini Castelli[3], D.Anfossi[3]
[1]CESI, Milano, Italy
[2]Dipartimento di Scienze e Tecnologie Avanzate, Universita' del Piemonte Orientale, Alessandria, Italy
[3]ISAC-CNR, Torino, Italy

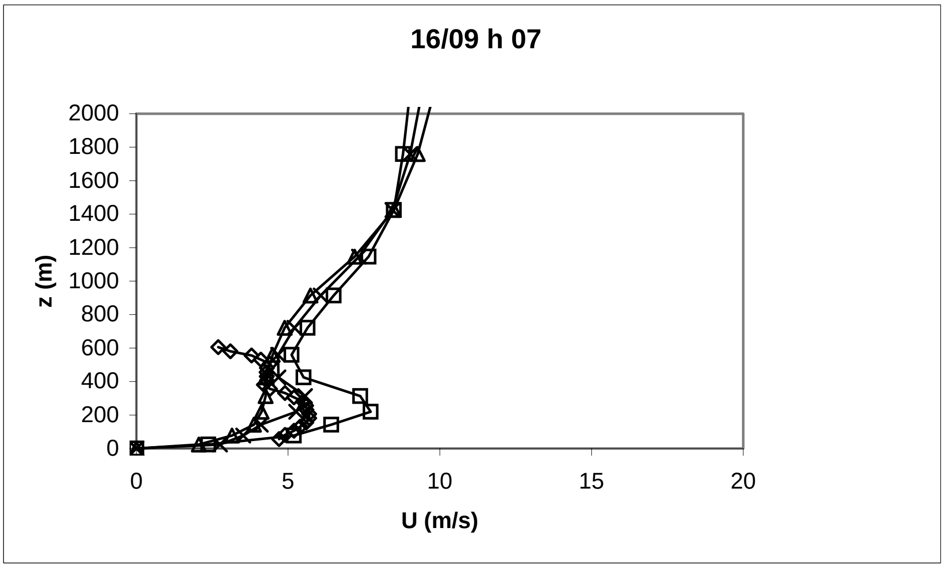
INTRODUCTION

This work is performed in the frame of a programme aimed at improving the turbulence description in the RMS (RAMS-MIRS-SPRAY) modelling system for the simulation of atmospheric pollutant dispersion in complex terrain. Here, we simulated the TRACT tracer campaign, which was already simulated with the RMS standard version (Carvalho et al., 2002). In this case we reproduce the experiment employing the latest version of alternative turbulence closures, accounting for the 3D dynamical equation for the turbulent kinetic energy and a diagnostic equation for its dissipation rate. The mesoscale atmospheric model RAMS is used to simulate the mean flow and turbulence, while the parameterisation code MIRS estimates the turbulent and boundary layer parameters for the Lagrangian stochastic dispersion model SPRAY. The complex characteristics of the considered scenario, both concerning the meteorology, the topography, and the different stability conditions, allows to assess the ability of the turbulent models to account for the non-homogeneities in both vertical and horizontal directions, considering that the usual turbulent parameterisations work in horizontal homogeneity. The importance of this improvement has been recently proved by us applying the RMS system in schematic and controlled conditions (Ferrero et al., 2003). The present work represents a development for applications in real atmospheric conditions and complex terrain. The results of the comparison between the simulated and observed flow and turbulence fields are presented. Finally, the mean concentration fields are compared in terms of statistical indexes and scatter plots as prescribed by the model evaluation kit.

In the version of RAMS here used, we have introduced, beside the Mellor-Yamada 2.5 (Mellor and Yamada, 1982, M&Y) turbulence closure, the E-l closure, where l is the turbulence length scale. In a previous work (Trini Castelli et al. 2001) we showed that this last reproduces the flow and the turbulent fields in a wind tunnel experiment better than the Mellor-Yamada 2.5 model. The influence of the different turbulent closures on the dispersion process is tested by comparing the SPRAY simulations with the observed tracer concentration fields.

RMS is based on a combination of the meteorological model RAMS, the interface code MIRS and the Lagrangian particle model SPRAY. RAMS **(**Regional Atmospheric Modelling System) is a prognostic model, that was developed at the Colorado State University (Pielke et al., 1992). The interface code MIRS (Trini Castelli and Anfossi, 1997), uses the RAMS outputs and calculates the parameters for the Lagrangian model SPRAY, not directly given by the RAMS. SPRAY (Tinarelli et al., 2000) is a Lagrangian stochastic particle model designed to study the pollutants dispersion in complex terrain. It is based on a three-dimensional form of the Langevin equation for the random velocity (Thomson, 1987) whose deterministic coefficients depend on the Eulerian probability density function (PDF), of the turbulent velocity and is determined from the Fokker-Planck equation. In the two horizontal directions the PDF is assumed to be Gaussian. In the vertical direction the PDF is assumed to be non-Gaussian (to deal with non-uniform turbulent conditions and/or convection).

The turbulent quantities needed as input to SPRAY are: the three standard deviations of the wind fluctuation components (σ_i) and the three Lagrangian time scale (T_{Li}). The turbulent model gives σ_i, whilst T_{Li} are obtained from the relationships $T_{L_i} = \frac{K_{m_i}}{\sigma_i^2}$, where K_m is the diffusion coefficient of momentum.



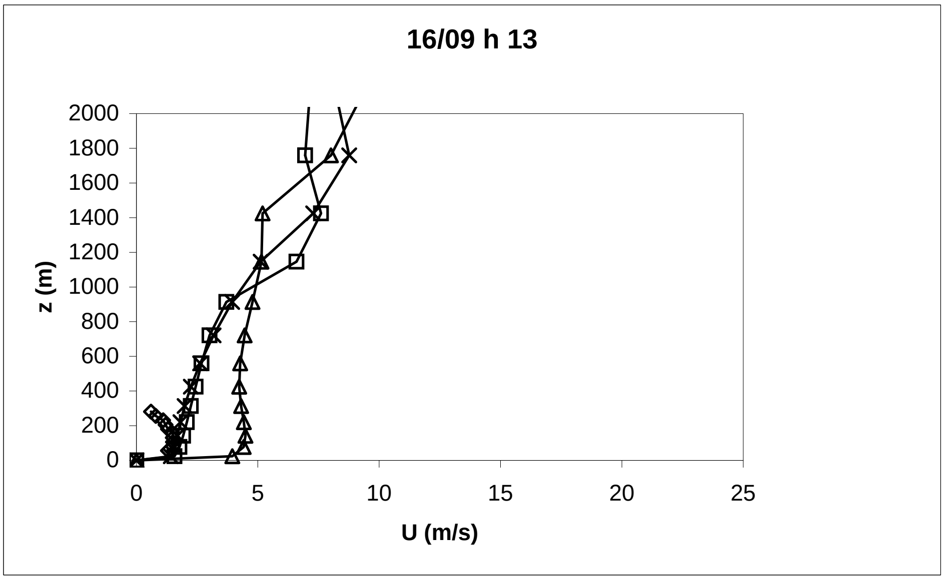


Figure 1: Velocity vertical profiles from Sodar measures (diamonds), M&Y (squares), isotropic E-l (triangles), E-l with horizontal deformation (crosses) models

STANDARD *E-L* CLOSURE MODEL

The E-l model is based on the turbulent kinetic energy E equation:

$$\frac{dE}{dt} = \frac{\partial}{\partial x_j} K_E \frac{\partial E}{\partial x_j} + P - \varepsilon$$

where $P = -\overline{u'_i u'_j}\frac{\partial \overline{u}_i}{\partial x_j} + \delta_{i,3} g \alpha \overline{u'_i \theta'}$ is the shear and buoyancy production term; α is the thermal expansion coefficient and

$$\overline{u'_i u'_j} = -K_m \left(\frac{\partial \overline{u}_i}{\partial x_j} + \frac{\partial \overline{u}_j}{\partial x_i} \right) + \frac{2}{3} E \delta_{ij} ; \qquad \overline{u_i' \vartheta'} = -K_h \frac{\partial \overline{\theta}}{\partial x_i}$$

$\varepsilon = c_\varepsilon \frac{E^{3/2}}{l}$ is the TKE dissipation, based on the Kolmogorov relation, while the diffusion coefficient is given by the Prandtl-Kolmogorov hypothesis $K_m = c_\mu E^{1/2} l$. The diffusion coefficient of heat and TKE are: $K_h = \alpha_h K_m$ and $K_E = \alpha_e K_m$.

We performed different simulations by using different closure models. The first simulation considered the M&Y model, as a basic configuration of the model also used in the previous work (Carvalho et al. 2002). The second turbulence model was the E-l model, in its standard isotropic formulation. Then we introduced an anisotropic version of this closure coupling it with an horizontal diffusion coefficient based on the deformation strain tensor and the grid spacing, as similarly done in RAMS for the M&Y closure.

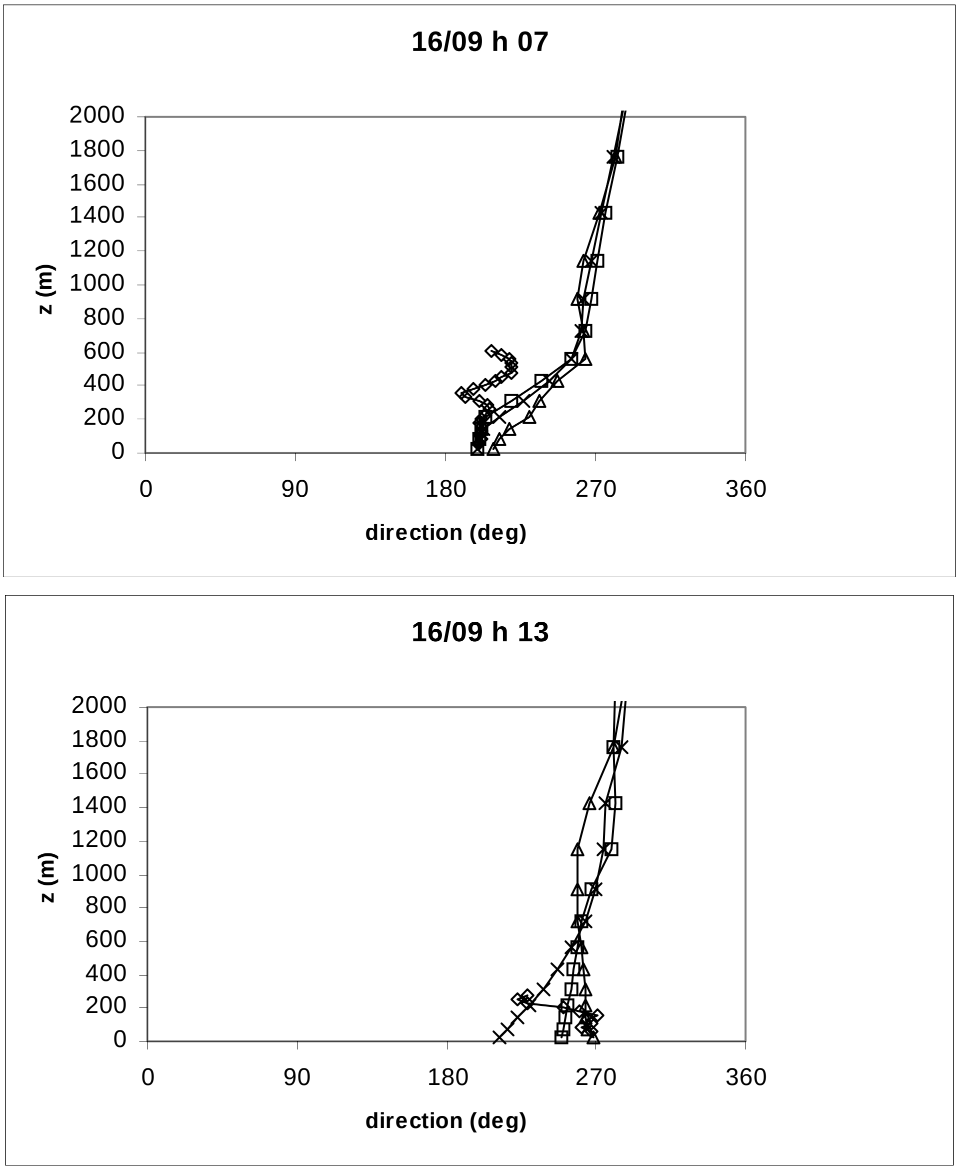
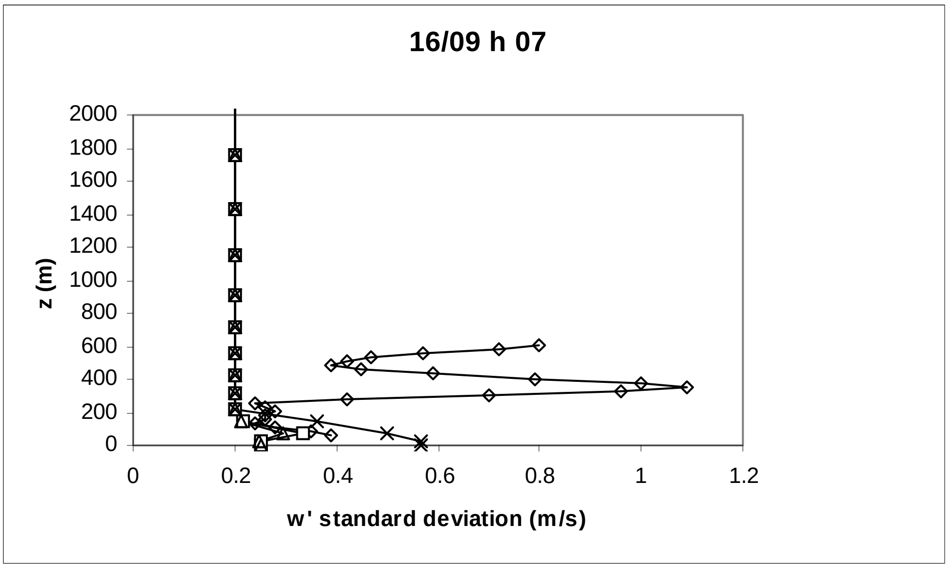


Figure 2: Velocity direction vertical profiles from Sodar measures (diamonds), M&Y (squares), isotropic E-l (triangles), E-l with horizontal deformation (crosses) models.

RESULTS

RAMS was run by using four nested grids with horizontal resolution equal to 60000 m, 15000 m, 5000 m and 1667 m respectively. First of all we compared the mean flow and turbulence fields provided by the different closure models with the measurements. In Figure 1 some examples of the velocity vertical profiles of the different models compared with Sodar measurements are depicted for two different hours. It can be seen that, despite giving comparable results some differences can be observed in the lower layers. In Figure 2 the wind direction vertical profiles are shown. Also in this case some discrepancies are presents near the ground, particularly in the highly convective conditions (13.00 LST).
Examples of the comparison between observed and modelled vertical velocity fluctuation standard deviation are shown in Figure 3 in term of vertical profiles. While at 7 LST all the models give the about the same values, at 13 LST, in convective conditions, different profiles are produced by different models.



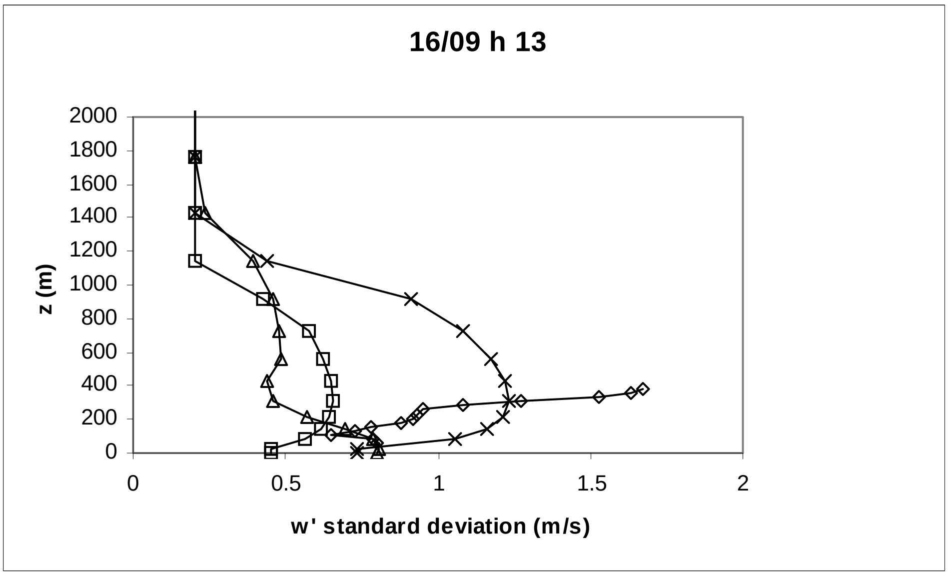


Figure 3: w' standard deviation vertical profiles from Sodar measures (diamonds), M&Y (squares), isotropic E-l (triangles), E-l with horizontal deformation (crosses) models.

Using the output of RAMS simulations in the MIRS code, the flow and turbulence fields needed to SPRAY were prescribed for each closure models considered.

Concerning the mean concentration predicted by the models, they are compared with the measurements in Table 1, in term of the usual statistical indexes. For sake of comparison, we also considered the Mellor and Yamada closure model with the Hanna (1982) parameterisation for wind velocity fluctuation standard deviations and Lagrangian Time scales. It can be observed that the best performance is obtained with the E-l model, both in the isotropic and anisotropic cases.

Table 1: Statistical indexes

Model	Mean	sigma	bias	nmse	cor	fa2	fb	fs
Observed	0.6	1.1	0.0	0.0	1.0	1.0	0.0	0.0
E-l DEF	0.8	0.7	-0.2	2.0	0.4	0.1	-0.3	0.5
E-l ISO	1.2	1.7	-0.6	2.9	0.6	0.3	-0.6	-0.4
M&Y Hanna	0.5	0.5	0.2	5.2	-0.03	0.1	0.4	0.7
M&Y	1.6	1.7	-1.0	4.1	0.2	0.0	-0.9	-0.5

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