A REFINEMENT OF AERMOD RESULTS BY MEANS OF MESOSCALE MODEL SIMULATION

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INTRODUCTION

AERMOD is an air pollution model which possibly incorporates all the current understanding of dispersion and micrometeorology to model the impact of sources at short distances. AERMOD, can be considered the choice model for short-range regulatory scenarios. Between all its capabilities, it can make use of the more advanced meteorological information such as that produced by a mesoscale model, namely RAMS.

In this paper we present a technique to extract data from the mesoscale model RAMS, ingest it into AERMOD meteorological preprocessor AERMET, and then run AERMOD to produce concentration output. In addition to the standard wind, temperature, and moisture variables, we have extracted parameters from RAMS such as mixing heights, surface roughness, cloud fraction, friction velocity, and surface heat. This approach is useful mainly in a complex coastal area where RAMS calculations illustrate the impact of mesoscale features, notably local winds, land and sea breezes. The soil characteristics and the complex orography significantly affect the modelling because of the strong surface and terrain forcing of meteorological processes.

We have considered a set of AERMOD runs using RAMS data as input and compared the results with AERMOD runs made using surface and upper air data from Local Airbase Station.

THE MODELS

AERMOD is a steady-state Gaussian plume model designed to handle both flat and complex terrain modeling computations. The model incorporates updated treatments of the boundary layer theory, understanding of turbulence and dispersion and includes handling of terrain interactions. AERMOD requires a file of surface boundary layer parameters and a file of profile variables including wind speed, wind direction, and turbulence parameters generated by a meteorological preprocessor. The PBL parameterizations can be expressed by means of dispersion parameters (sigma y and sigma z) that are based on either measured or estimated turbulent intensities. Non-homogenous conditions throughout the PBL are taken into account improving the treatment of plume rise and enhancing the prediction of concentrations at complex terrain receptors also by incorporating the concept of a critical dividing streamline. The AERMOD modelling system consists of two preprocessors and the dispersion model. AERMET (*EPA, 1998*) is the meteorological preprocessor and AERMAP (*EPA, 1998*) is the terrain preprocessor that characterizes the terrain, generates receptor grids and facilitates the generation of hill height scales.

Sensitivity analysis of AERMET input parameters (*Latini G. et al, 2001*) revealed the importance of these in determining model-predicted maximum concentrations.

A mesoscale model (RAMS version 4.3) was used as a modelling tool to investigate mesoscale wind flow patterns in the study area. RAMS is a versatile modelling system capable of simulating flows from the scale of a global hemisphere to the scale of a building (*Pielke et al., 1992*) with several options including multiple nesting, several convective and boundary layer parameterisation options.

It is constructed around the full set of primitive dynamical equations that govern atmospheric motions, and supplements these equations with optional parameterisations for turbulent diffusion, solar and terrestrial radiation, moist processes including the formation and interaction of clouds, sensible and latent heat exchange between the atmosphere and multiple soil layers. Prognostic soil-vegetation relationships are used to calculate the diurnal variation of temperature and moisture at the ground-atmosphere interface. Turbulence sensible heat, latent heat, and momentum fluxes in the surface layer are based on similarity equations.

For this study RAMS was run with three nested grids with a fine grid of 1 km horizontal spacing, and the vertical distribution of atmospheric flow and meteorological parameters have been simulated considering effect of complex terrains.

The input data for initial and lateral boundary conditions have been downloaded from National Center for Environmental Prediction (NCEP) reanalysis products. A case of mesoscale circulation during the winter of 2001 is presented.

THE INVESTIGATED AREA

A coastal region is influenced by many meteorological phenomena due to air-sea interactions to intense large-scale wind systems. Mesoscale flows in coastal regions are mainly determined by land-sea temperature contrast that drives land-sea breezes (*Fast, J. D, 1995*) and by the orography that drives mountain-valley breezes while the shape of coastline has an effect on mesoscale wind flow. All these phenomena strongly influence various scalar fields including moisture and air pollution concentrations.

The Esino Valley (in the middle of Italy) is particularly interesting due to its composite orography (*Latini G. et al., 1999*) and the presence of an inner city that can complicate small-scale circulation patterns due to its urban heat island effect. The Valley is surrounded by hillsides sharply rising to mountain height. Its climate is classified under sub coastal where there is an all year round sea breeze. Topography in the Valley area is fairly complex and the proximity to the coast implies a significant interaction between the sea and valley breezes. The sea-breeze/land-breeze circuit (SBLB) is a meso-scale circulation of air due to the differential heating and cooling of the land-and sea-surfaces in the coastal zone.

The first step towards the modelling of convective, valley and/or sea breeze circulation for the Esino Valley was accomplished through the application of RAMS model for several events. It proved to be suitable for numerical studies of sea breeze circulations and it is capable to capture diurnal variability of wind and convective cloudiness.

MODEL APPLICATION

AERMOD is recommended by the EPA as the preferred dispersion model for general industrial modelling scenarios. Its performance was evaluated (*Latini G. et al., 2002*) against observed concentrations for impacts due to pollutants emitted from Esino Valley refinery located by the sea.

The model was run to predict short-term, one-hour average concentrations at each receptor using one month of winter meteorology. A discrete Cartesian receptor grid network containing 400 receptors with a resolution of 500 meters was used. For this study, the data are related to the month of December 2001.

In the first simulation AERMOD modelling system has been initialized using the wind fields predicted by RAMS. AERMOD was used to calculate 1-hour average values for each day of the selected period. After completion of 48–hour simulations resulting fields of temperature, wind and cloudiness (cloud liquid water content) were examined. The case of 3-4 December exhibits a slight simpler wind patterns. Wind patterns (Fig.1a, Fig.1b) exhibit diurnal variations, which may be mainly due to the effect of thermal convection as the land–sea temperature.

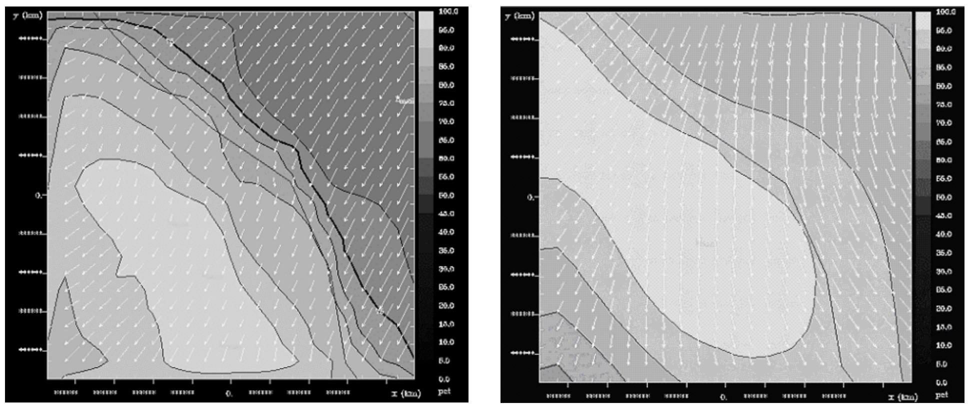

Fig1a,1b. Evolution of surface winds.

The 7.5-minute Digital Elevation Model (DEM) data were used for this modelling analysis for terrain data and their preprocessing. The DEM data file was generated from the topographical maps, and contains point elevations at regularly spaced horizontal intervals of 30m.
A triple nested grid was adopted with grid spacing of 8 km, 4 km and 1 km for the finest. Dimensions of the smallest grid #1 were 11×11 km centered at Ancona city (43° 35' 13"N, 13° 30' 56"E). Figures 2a and 2b show the topographic features and the double fine grid configuration of the geographic area respectively.

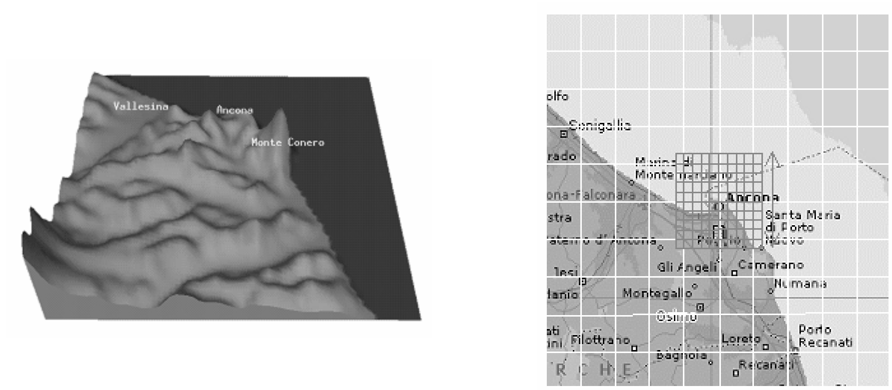

Fig.2a,2b. Topographic depiction and the selected double nested grid of the analysed area.

In the second simulation AERMOD was run using upper air data from the closest Local Airbase, namely Pratica di Mare Airport (PMA) and hourly surface station. The surface data, collected by the meteorological Falconara station, included: horizontal wind speed, horizontal wind direction, ambient temperature, humidity, pressure, and net solar radiation. The meteorological data preprocessor for AERMOD, AERMET, organizes data from the PMA upper air and hourly surface observation stations, and then estimates the necessary parameters for dispersion calculations. The source configuration was the same for each modelling input file as shown in table 1.

Table 1. The source configuration.

Point Source	Pollutant emission rate [g/s]	Stack Height [m]	Stack gas exit temperature [K]	Stack gas exit velocity [m/s]
stk1	0,1270833	60	473	3.05
stk2	1.31	52	470	3.05
stk3	1.31	35	714	28.09.00
stk4	0.08	54	811	5.09
stk5	1.31	60	505	4.03
stk6	0,1902778	60	463	20.09
stk7	1.31	55	637	10.09
stk8	0.08	22	640	5.05
stk9	0,0638889	50	657	3.05
stk10	0.53	28	553	2.03
stk11	1.05	54	523	3.07
stk12	1.18	54	523	3.06
stk13	5.25	15	773	5.09
stk14	39.44.00	50	393	11.04
stk15	0.03	50	423	2.01

RESULTS

The modelling results for both RAMS-AERMOD and AERMOD simulations are summarized in Table 2. The relative locations of the source and the predicted 1-hour maximum impact locations are depicted in Figures 3a and 3b. As shown in Table 2, the date, time and location of the highest 1-hour concentration impacts are the same. This location is close to the emission source.

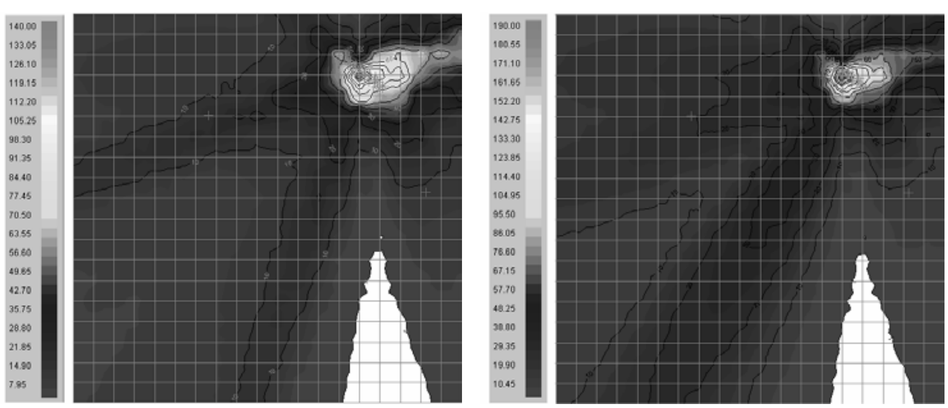

Fig. 3a, 3b. AERMOD and RAMS-AERMOD maximum predicted 1-hr concentrations

Table 2. Maximum predicted 1-hr NOx concentration.

Model	Max Concentration (μg\m^3)	Location of maximum	Time
RAMS-AERMOD	136.065	369276.41, 4833391.00	10.00 am
AERMOD	188.150	369270.91, 4833398.22	10.00 am

From these results it is readily apparent that these two models will predict short-term averaged concentrations in a similar fashion when using identical input data. They show that AERMOD predicts a maximum 1-hour concentration during a neutral/unstable daytime situation in both cases. The positions of concentration maximums are almost the same while the value predicted using RAMS-AERMOD is slightly higher. In a first instance the difference between the two values is quite high. This is also important since Italian laws prescribe a value of 200 μg\m^3 as a first limit. The AERMOD value is very close to such limit so to possibly determine a stop of the source or whatever. Based on our experience we can postulate that the RAMS-AERMOD value is the most likely to be exact. This could be due to the evident capability of RAMS to model PBL parameters and its structure. However, it is evident that RAMS-AERMOD simulation was computationally very expensive. On the other side it seems suitable to provide high spatial and temporal resolution meteorological fields.

After each RAMS execution, all the results are collected and reorganized into a form that can be used by standard meteorological analysis tools. To improve computational performance it would be enough to use coarse grid spacing, for example the spacing of the finest grid 3Km could be a good compromise between spatial resolution and available computational power.

We can conclude that the use of RAMS as a meteorological preprocessor for AERMOD shall be used whenever a special refinement of result must be accomplished and/or the predicted values are around law limits to check the results of AERMOD stand-alone run. The computational needs of RAMS must be taken into account. Thus, in less critical situations, AERMOD can be used as a stand-alone tool with good results. In particular, the receptor maximums are likely to assume more or less the same positions.

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