Development of a computer system for control and prevention of air pollution in the Valencia Port (Spain)

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1 Introduction

More than 3.8 millions of tons of solid bulks are annually handled in the Valencia Port located in the Mediterranean coast of Spain. The handling of cement, clinker, coal, minerals and other food products like soya beans and flour, produce an important contribution to the PM10 concentration in the air. There are two factors determining the PM10 levels: (i) the way in that the solid bulks are handled, and (ii) the meteorological conditions.

The objective of this paper is to show the development of a computer system for control and prevention of the air pollution produced due to the solid bulks handling in the Valencia Port and the previous studies. The work has consisted of two phases: first, the evaluation of the impact of the solid bulk handling in the port and its surrounding areas; and second, the development of modelling tools to control the atmospheric pollution.

2 Evaluation of the impact of the solid bulk handling on PM10 concentrations

The climatic conditions in the studied area (figure 1) correspond to those of a typical coastal western Mediterranean region. The Azores subtropical anticyclone and the deepening of the low-pressure systems in the Mediterranean Sea are the main factors influencing on the climatic conditions. The summer weather is usually dry and hot but temperated by the sea breezes while in winter, the days are not cold. During the fall season, highly intense rain episodes occurs. The sea breeze is the most dominant feature of the mesoscale flows, specially in summer time. Foehn effects are also detected when westerly blows in this region.

The evaluation of the impact of the solid bulk handling in the Valencia Port has been done by using a dispersion model fed with the meteorological fields estimated by a mesoscale meteorological model. The models were run under 38 meteorological scenarios which corresponds to the 11 synoptic conditions affecting the studied area and taking into account their seasonal occurrence (Table 1). There were not measurements of PM10 concentrations in locations in or close enough to the Valencia Port to be used in this study.

The TVM model is a three-dimensional mesoscale vorticity mode numerical model for complex terrain. A complete explanation of the formulation and some applications of this version of the TVM model can be seen in Schayes et al. (1996). The used version for this study (TVMNH20a) was developed by Thunis (1995) by using the vorticity approach for shallow thermal convection; that is, it is a non-hydrostatic, anelastic and Boussinesq mesoscale model. TVM includes a soil model based on the ‘force-restore’ approximation for computing surface soil temperature, the Penmann-Monteith formulation for the surface soil specific humidity and the Sasamori scheme for radiation. The turbulence fluxes are computed by means of a 1.5 order closure based on prognostic equations of turbulent kinetic energy. Among several atmospheric modelling exercises (including validation and comparison with other models) in Europe and America, we can pointed out the cases of Fos (France) (Bornstein, 1996), Athens (Thunis et al., 1993) and Madrid (Martín et al, 2001).

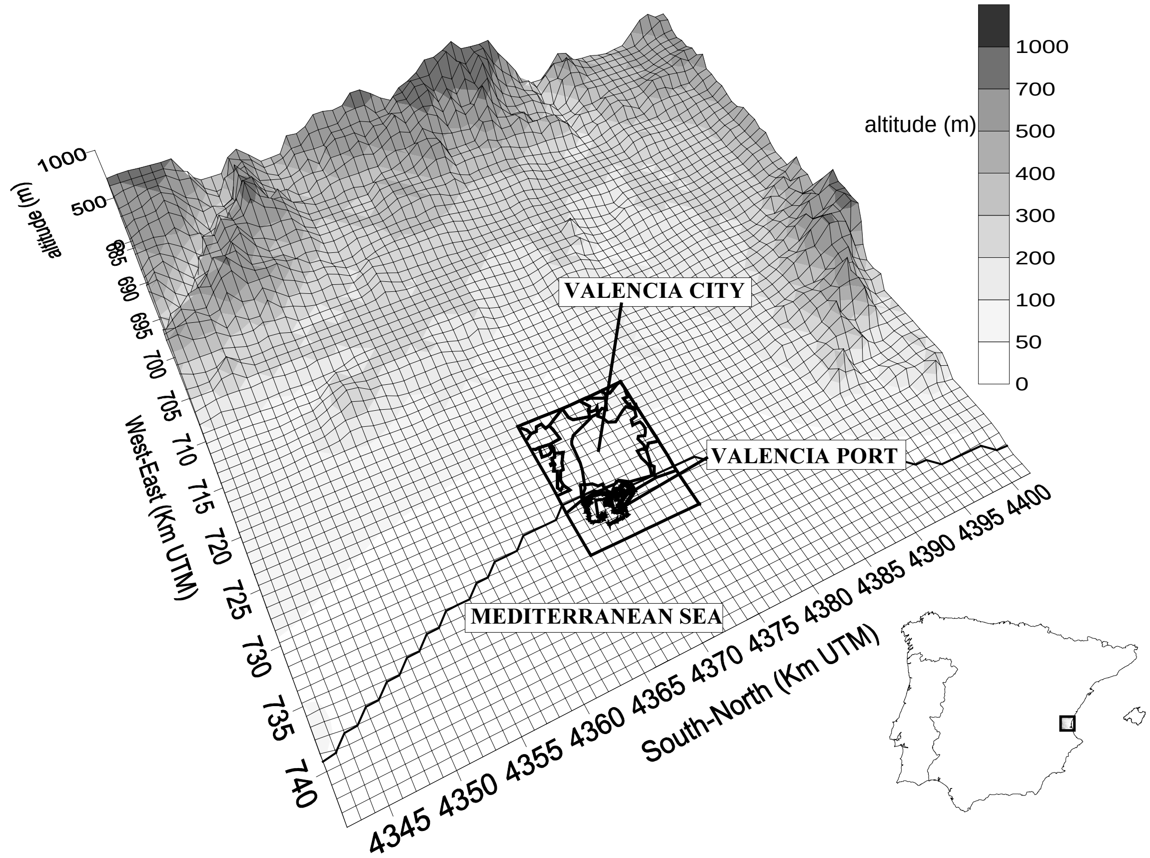

Figure 1 Map of the modelling domain showing the location of the Valencia City and its port.

Table 1 Scenarios used for modelling.

Synoptic situation	Winter	Spring	Summer	Autumn
1. Anticyclone over the Iberian Peninsula	■	■	■	■
2. Anticyclone over the British Isles or Scandinavian Peninsula	■	■	■	■
3. Eastern Atlantic-Mediterranean Anticyclone	■	■	■	■
4. Low Pressure over the British Isles	■	■	■	■
5. Low Pressure over the Western Mediterranean Sea	■	■	■	■
6. Thermal Low Pressure over the Iberian Peninsula		■	■	■
7. Atlantic Low Pressure	■	■	■	■
8. Low Pressure over the Cadiz Gulf	■		■	■
9. High Pressure System extending from Atlantic Ocean to Europe.		■	■	
10. Ibero-African Through	■	■	■	■
11. Very low pressure gradient		■	■	

The Topographic Vorticity-mode Model (TVM) was used to simulate the meteorological field evolution during a complete day corresponding to each of the 38 scenarios. The meteorological domain was 60x60 Km with a resolution of 2x2 Km and with 24 vertical levels. The top of the domain was 7600 m above mean sea level. The minimum vertical separation was 20 m for the lower levels and 600 m for the highest ones. The period of simulation was 27 hours and the model was initialised at 2100 UTC with the potential temperature and wind profiles extracted from the NCEP reanalysis for the reference year (1992). Surface station data was used to complete the initialisation of the model.

The dispersion of pollutants is computed by the MEsoscale Lagrangian PUFF model MELPUFF (Martín et al, 1999). The simulation period is 24 hours assuming a single point source with a constant emission rate of 100 Kg/hour and the height of source equals to 10 mts above the ground. The location of the source corresponds to the dock were the solid bulks handling is made by a method that implies the highest emission of particles to the atmosphere.

MELPUFF is based on the MESOI 2.0 model (Ramsdell et al, 1983). MELPUFF can use three-dimensional meteorological fields (wind speed and direction, temperature, mixing depth and turbulence parameters) provided by mesoscale prognostic meteorological models such as CSUMM or the above mentioned TVM. MELPUFF also includes a diagnostic wind field model, which can be turned on instead of the CSUMM or TVM simulations. This option is the operational one in the present version of SICAH (Martín et al, 1999). The puffs are considered as following a Gaussian distribution of pollutant concentration. The interaction with the mixing layer top and the ground is represented with the concepts of reflections and virtual sources. MELPUFF can be initialised by the observed pollutant concentration.

For computation of the pollutant diffusion, either MELPUFF assimilates the diffusivity coefficients estimated by the outputs mesoscale prognostic meteorological models by means of the Draxler parametrisation, or it uses classical parameterisations (such as “Open Country”, “Desert”, “US NRC” or “US Army”) when those are not available. Building-wake effects on pollutant dispersion are also included. The estimation of dry deposition of pollutant is carried out using a source depletion dry deposition model based on the estimates of the deposition velocities as function of the aerodynamic, quasi-laminar and surface resistances. Wet deposition is also estimated by a simple washout model. MELPUFF compute the dispersion of pollutant emitted from multiple point sources. MELPUFF provides surface pollutant concentration and deposition distribution, surface wind fields every 15 minutes and also 15-minute averaged concentration of pollutant in user-selected point receptors, along with the estimates of the contribution of every pollutant source to the pollution in selected receptors.

As conclusions, we can point out that the scenarios resulting in a significant impact on urban areas are related to persistent easterly flows (for example, scenarios 10-all seasons) or sea breeze conditions during daytime (scenarios 3, 6, 7 and 11). However, the highest impact was estimated for scenarios 2-winter, 3-autum, 10-winter, spring and autumn and 11-summer during the evening, when inland flows and stable stratification occur. Scenarios affected by rain produces low levels of PM10 concentrations due to the enhanced wet deposition. Of course, scenarios, in which offshore winds are dominant, corresponds to non-impact in urban areas. Results of the dispersion modelling for the scenarios 2-winter and 6-spring are shown in figure 2.

3 Computer system for control and prevention of air pollution in the Valencia Port

A computer system (CS, hereafter) has been developed for control and prevention of PM10 concentrations in the Valencia Port (Crespí et al., 2000 and 2001). The core of this system is the MELPUFF dispersion model, which has built-in a diagnostic wind field model. A postprocessor is included to make computations of surface instantaneous (every 10 minutes), hourly and 24-hour averaged PM10 concentrations for a high spatial resolution grid (100x100 m) and for the PM10 monitor locations. CS can deal with three different types of scenarios: real-time, past and hypothetical cases and a maximum of 20 simultaneously working sources are allowed for a maximum simulation period of 24 hours running in the presently conventional desktop personal computers. A friendly-user interface has been developed for this system, which includes several types of graphics (surface concentration, surface wind fields, predictions versus observations plots, port maps, animations, etc.).

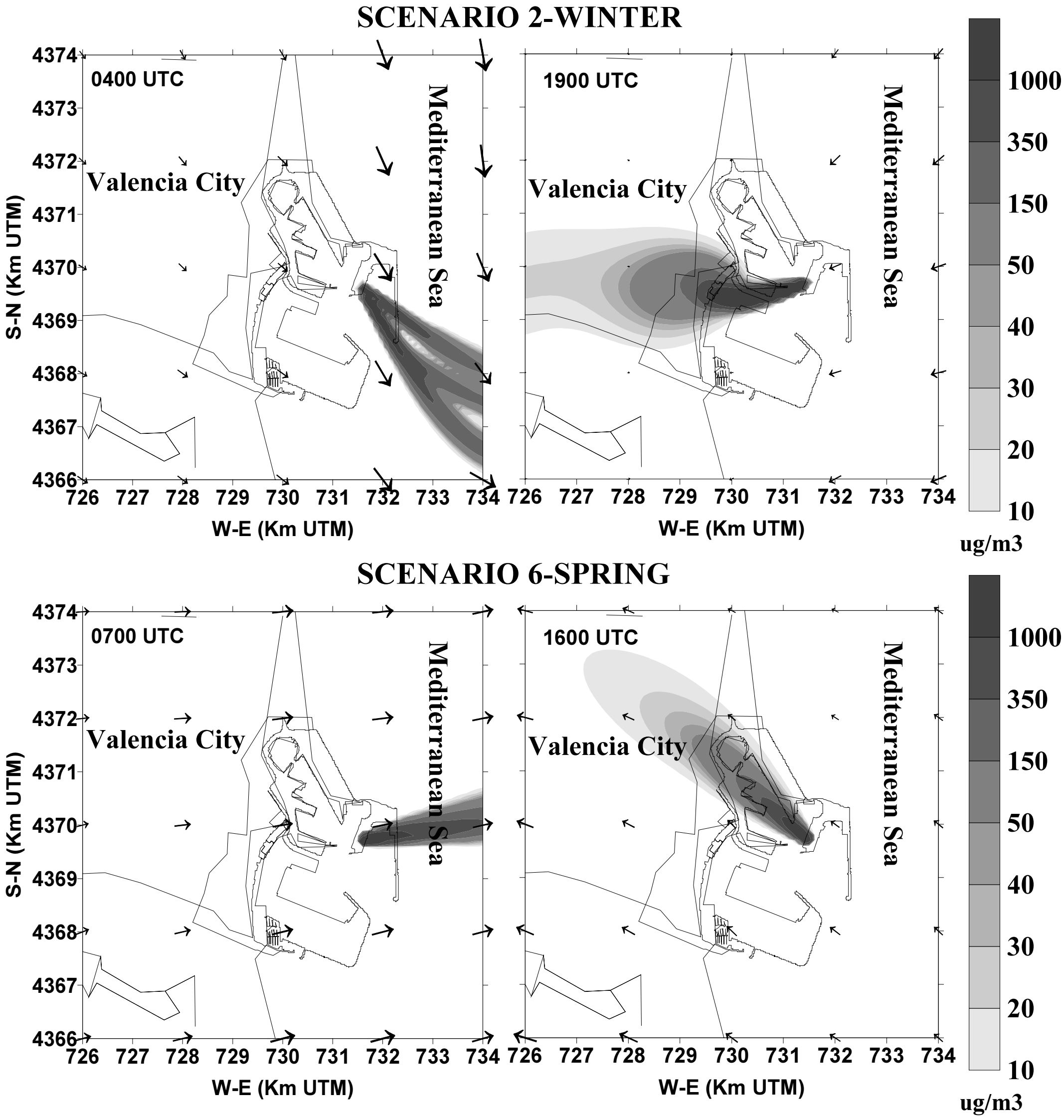

Figure 2 Surface concentration of PM10 estimated with MELPUFF for some selected scenarios.

A database is developed and updated in real-time including information about the PM10 concentrations and meteorological data recorded by sensors deployed in the port. The locations of the PM10 monitors and meteorological towers have been determined as a result of the previous study about the dispersion of PM10 shown in section 2. The results of the simulations made by CS and a 'background' PM10 concentration data due to the Valencia City are also stored in the database.

An important feature of the system is that recursively and automatically MELPUFF simulations can be done to estimate the PM10 emission rate, which fits better the observed concentration of PM10 recorded in the monitors. It can be done because of the capacity of the MELPUFF model to label the pollutant clouds depending on the source from where they were released and then to evaluate the contribution of every source to the estimated pollution in the PM10 monitors locations. This solves the problem of the generally unknown (or uncertainty of) PM10 emission rates for the typical sources in a port and it could also allow to make a data base about emission rates estimated by CS for different kind of operations and meteorological conditions.

For real-time and past cases, it uses meteorological data collected from stations deployed in the Valencia Port. The users have to input a set of data corresponding to the pollutant sources (location, type, starting time and duration of operation, type of handled bulk, etc).

For hypothetical cases, the system uses a database of meteorological fields. This database corresponds to the wind fields obtained with the TVM model for the 38 scenarios shown in section 2.

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