Comparison of a Gaussian (ISC3) and a Lagrangian Particle Model (SPRAY) for Regulatory applications in Flat and Complex Terrain Sites Representative of Typical Italian Landscape

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1 Introduction

The evaluation of the impact on air quality of industrial emissions has to verify the attainment of air quality standards that usually state limits on yearly and seasonal statistics of pollutant. The application of different modelling tools can give unlike results that can even influence the compliance with legislation for the considered emission. One of the main aims of the European harmonisation initiative is to verify these differences and to define guidelines to help the user to choose the proper modelling tool for any particular atmospheric dispersion study. This problem assumes particular relevance in complex conditions like those that affect the coasts of the Mediterranean Sea, where land/sea interface and topography give rise to complex circulation patterns. The performances of the Gaussian regulatory model ISC3 (US EPA, 1995) and of the modelling system composed by the mass-consistent meteorological model MINERVE (Aria Tech., 1995) and by the Lagrangian particle model SPRAY (Tinarelli et al., 1994) - hereafter MS - have been compared in two practical applications concerning industrial emissions at coastal sites. The analysis of different geographic and climatic conditions can help to define the applicability limits of dispersion models.

The first study regarded two thermal power plants (TPP) located in Fusina and Porto Marghera, nearby Venice. The site is characterised by flat terrain, the land use is mainly of industrial/urban type nearby the emissions and agricultural inland. The shallow depth of the Venice Lagoon and of the Adriatic Sea causes a relevant yearly excursion of the sea surface temperature, that limits the occurrence and intensity of sea breezes. Local wind measurements generally show a weak horizontal variation and vertical shear of the winds.

The second study concerned a TPP sited in Vado Ligure, on the northern Mediterranean coast of Italy. The region is characterised by very complex topography and climatology dominated by the superposition of land/sea breezes and slope flows, during fair weather conditions. In a previous study (Finardi et al., 1999) long term average concentrations have been estimated from the simulation of short term episodes, that has been performed with the MS modelling system. These results have been used as a basis for the present intercomparison.

2 The flat coastal site of Fusina (Venice)

The Gaussian model ISC3 and the MS modelling system have been applied to compute ground level concentrations (GLC) due to the emissions of two TPP located few kilometres apart in Fusina and Porto Marghera (Brusasca e Sanavio, 1999). The simulations covered a period of one year, from April 1st 1997 to March 31st 1998. The available meteorological data included SODAR wind profiles and two surface stations. MINERVE model used all the available meteorological data to reconstruct 3D wind and temperature fields. For ISC3 wind speed and direction were extracted from the SODAR profile at the vertical level of 100 metres, while surface observations have been

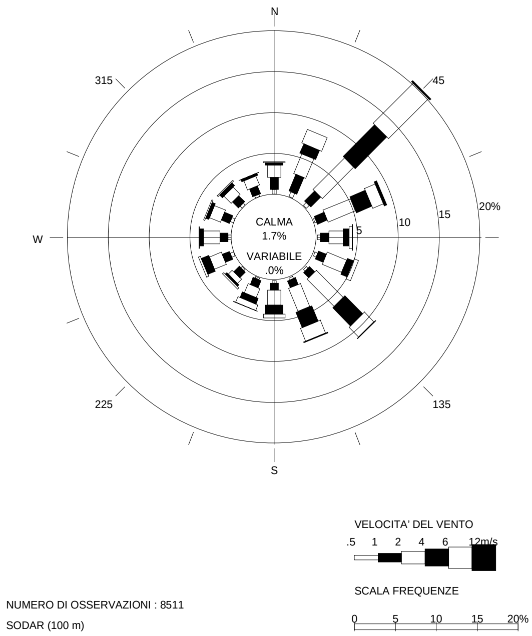

Figure 1 Yearly wind rose from the measurement level of 100 metres of the SODAR located in Fusina.

used to define the air temperature and to compute stability classes. The wind rose built from SODAR data (Figure 1) shows two prevailing directions: NE, mainly associated to neutral conditions, and SE, related to unstable conditions and sea breezes. For the local meteorological features this case study can be considered rather simple. The emission data of the power plants of Fusina and Porto Marghera are resumed in Table 1. All units have been considered working continuously all year long, with the exception of July and August when the power plants are stopped due to the limitation imposed to thermal discharges into the Venice Lagoon.
For both models the computational domain was identified by a square area having side dimension of 30 km, and space resolution of 500 metres. Four land use classes (sea, bog/marshes, crops and urban) have been considered by SPRAY. ISC3 simulation have been performed using Briggs Open Country sigmas, preliminary simulations showed large overestimations of GLC if Urban sigmas were employed. Hourly average concentrations have been post-processed to compute long term statistics requested by the Italian standards and by the European guidelines.

Table 1 Emission details for the power plants of Fusina (FS) and Porto Marghera (PM).

Unit	Power (MW)	Height (m)	Stack diameter (m)	Temp. (°C)	Outflow velocity (m/s)	SO_2 (g/s)	NO_X (g/s)	TSP (g/s)
FS 1	165	65	4.5	140	14.9	250	96	7.4
FS 2	171	90	4.0	140	19.6	260	99	7.6
FS 3-4	2x320	150	6.5	110	27.6	228	114	28.5
PM 2-3	2x70	100	4.0	120	15.3	263	119	15.0

The general features of the concentration fields produced by MS and ISC3 are comparable. Both models identify two areas interested by GLC, that are located NNW and SW of the emission points (Figure 2 and 3), reproducing the wind rose characteristics (Figure 1). The yearly average concentrations of SO_2 are almost similar, but the 50^{th} percentile of daily average concentration patterns (Figure 2) already show differences that cannot be neglected. While ISC3 describes impact only in the SW area, with maximum values located between 5 and 15 km from the sources, MS predicts a ground level contribution in the NNW direction, with its maximum located near the sources. This latter feature is due to the rotation of wind from NE to SE, that occurs in the afternoon and carries back pollutant previously dispersed in SW direction. The differences grow when higher percentiles of daily and hourly averages are examined. The 98^{th} percentile of hourly average concentration of NO_X (Figure 3) shows that ISC3 predicts maximum concentrations over 50 $\mu g/m^3$ NW of the emissions, where SPRAY computes values slightly higher than 20 $\mu g/m^3$ within a very limited area. Minor differences are detected on the SW region of the computational domain, even if SPRAY limits the pollutant impact to a smaller area located farer from the sources. The different position of maximums and smaller area covered by equivalent concentration (e.g. 20 $\mu g/m^3$) are mainly due to the different approaches in the simulation of convective conditions and to the larger crosswind dispersion induced by time and space variations of winds that is taken into account by MS modelling system.

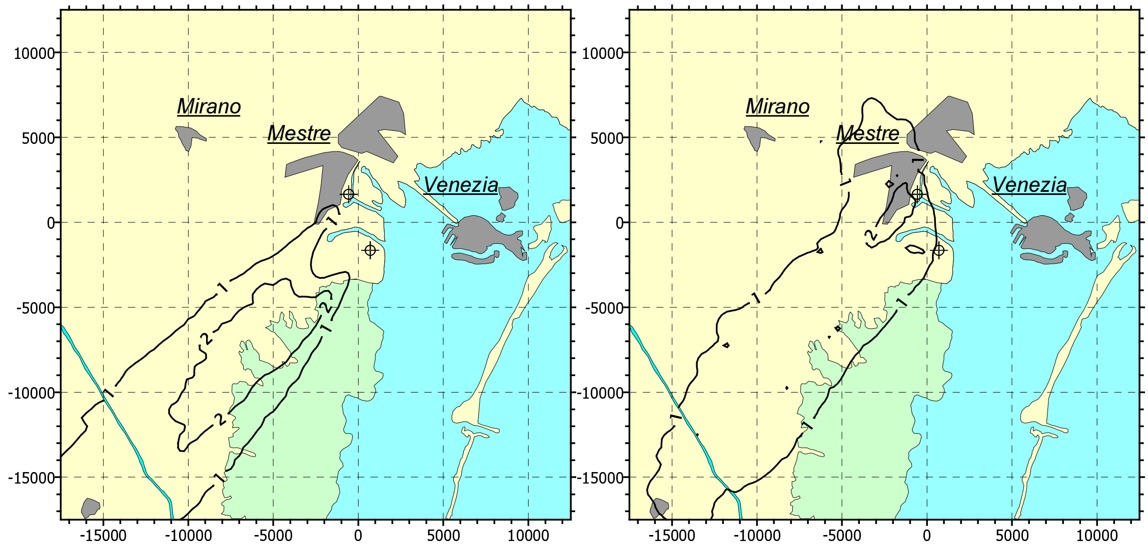

Figure 2 50th percentile of daily average concentrations of SO_2 predicted by ISC3 (left) and SPRAY (right). Sources location is indicated by symbol ⊕.

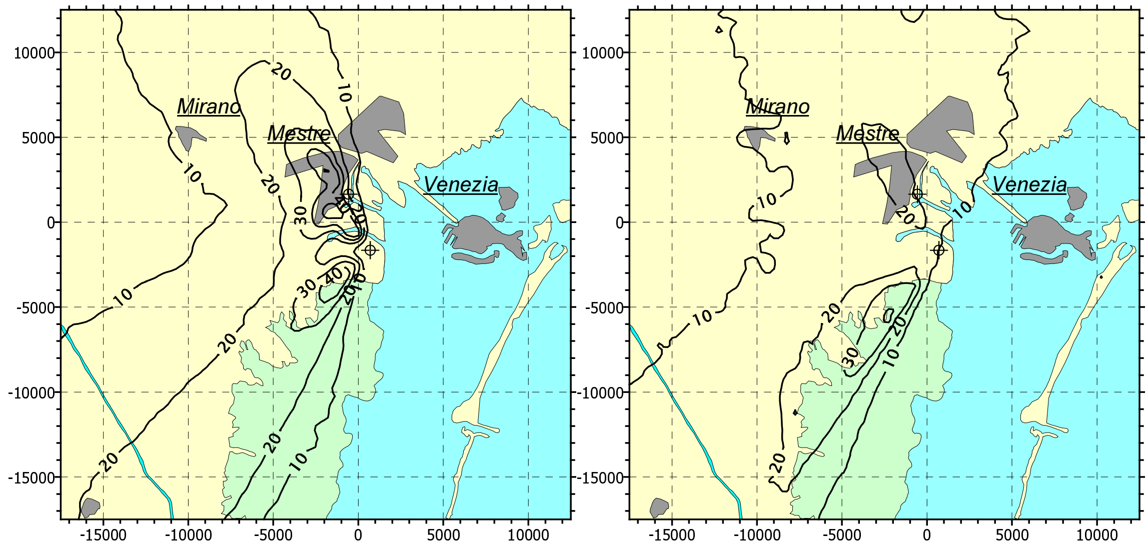

Figure 3 98th percentile of the hourly average concentrations of NO_X predicted by ISC3 (left) and SPRAY (right). Sources location is indicated by symbol ⊕.

3 The complex coastal site of Vado Ligure

The investigated site is located on the north-western Mediterranean coast of Italy, nearly 50 km west of Genoa. It is characterised by complex terrain with mountains rising over 1000 metres few kilometres inland. A coal/oil fired TPP is located less than 1 km inland. Intensive meteorological and air quality field campaigns have been performed on site (ENEL/PIN, 1999). Several surface stations, two SODARs, meteorological and ozone soundings have been operated during the campaigns. A peculiar characteristic highlighted by local measurements is the strong shear in wind speed and direction profiles. This last feature is quite critical for the description of trajectories of pollutant emitted by elevated sources. During a previous study (Finardi et al., 1999) the MS modelling system has been employed with satisfactory results to reconstruct short term episodes representative of different meteorological conditions.

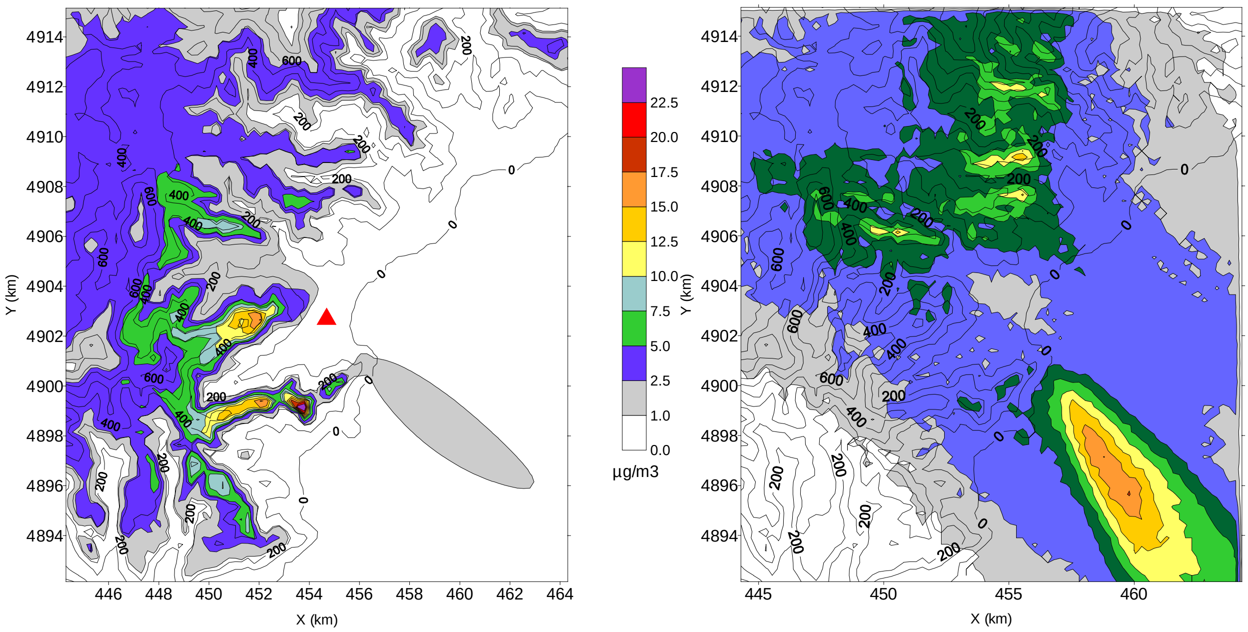

Figure 4 Ground level yearly average concentration of SO_2 ($\mu g/m^3$): (left) ISC3, (right) SPRAY driven by MINERVE. The red triangle indicates the emission location.

Due to the complexity of site and circulation, plenty of meteorological measurements (in particular soundings) needed to be used to reach a reliable reconstruction of flow and dispersion.

Table 2 Emission details for the power plant of Vado Ligure

Unit	Power (MW)	Height (m)	Stack diameter (m)	Temp. (°C)	Outflow velocity (m/s)	SO_2 (g/s)
VL 1-2	2x330	200	6.9	150	14.4	653

Hourly ground level concentration fields have been then used to build seasonal and yearly averages applying a method based on the statistic relevance of the weather type associated to each episode. The Gaussian model ISC3 has been applied to simulate the whole year that includes the previously analysed episodes, ranging from July 1997 to June 1998. Input wind speed and direction were extracted from the SODAR profile at the vertical level of 200 metres, while surface observations have been used to define the air temperature and to compute stability classes. During the considered period only two of the four units of the TPP were operating, emission data are resumed in Table 2. The computational domain has been defined to be coincident with that previously used by the MS modelling system, and is identified by a 20x23 km^2, with a space resolution of 250 metres, corresponding to the resolution of the available digital elevation model.

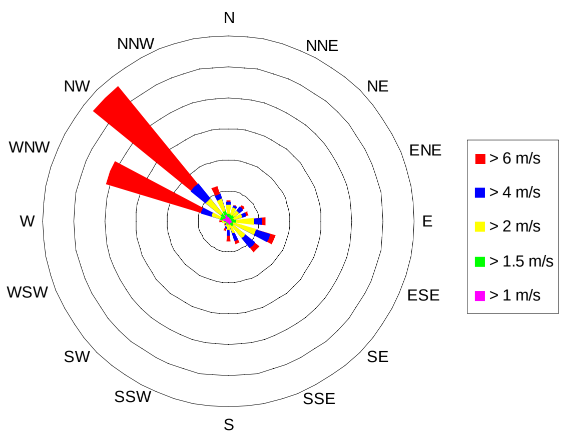

Figure 5 Yearly wind rose from the measurement level of 200 metres of the SODAR located in Vado Ligure.

The results obtained from ISC3 showed large differences from what previously obtained by MS. The seasonal and yearly average (Figure 4) concentration fields predicted by the models indicated areas of impact located over different portions of the computational domain. The ground level impact of pollutants described by ISC3 is essentially topographic, with maximum values located on the hills nearest to the emission location. This feature is mainly due to the steady state characteristic and to the scheme employed to describe of the plume interaction with terrain in neutral and stable conditions. The plume height is not modified and a direct impingement on topography is predicted. The more relevant impact areas are located in the SW region of the computational domain, while SPRAY describes the highest concentrations in the NW and SE regions. The maximum impact over land is here due to sea breeze conditions. No impact is foreseen by ISC3 on the flat coastal region, this feature is rather unlikely in a coastal location, where land/sea breeze cycles are expected to cause pollutant recirculation. The MS modelling system describes a weak concentration impact over all the coastal region in the range of about 10 km from the source. Moreover the average concentration fields produced by ISC3 do not reproduce the wind rose characteristics (Figure 5), that shows a clear NW-ESE polarisation.

4 Conclusions

A steady state regulatory model (ISC3) and a Lagrangian particle model (SPRAY) driven by a mass-consistent model (MINERVE) have been intercompared in two Italian coastal sites, that can be considered representative of “simple” and “complex” coastal dispersion conditions. The two studied models give congruous results only in the site of Fusina, characterised by weak space/time variations of wind speed and direction. The areas interested by pollutant impact are similar but relevant differences are detected in pollutant patterns for the different statistical indexes prescribed by air quality standards. Even in this simple conditions results provided by stationary and non-stationary models can not be considered equivalent. In the complex topographic and circulation conditions that characterise the site of Vado Ligure the results obtained by ISC3 and MS modelling system are completely dissimilar. Even seasonal and yearly average concentrations depict different impact areas. Steady state models implementing simple algorithms for complex terrain appear to be unable to reproduce relevant features of pollutant dispersion in conditions that can be considered typical for the Mediterranean coasts.

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