MODEL EVALUATION OF PARTICULATE MATTER CONCENTRATIONS DUE TO A COAL-FIRED POWER PLANT: INTERCOMPARISON OF GAUSSIAN AND LAGRANGIAN APPROACH

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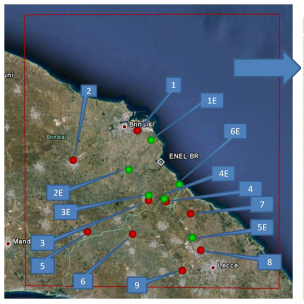
INTRODUCTION

Dispersion models are used for many purposes, but one of the most important is as indicators of ambient pollution levels for regulation and control purposes. For this reason, the accuracy of models and any differences in behavior between them represents a crucial problem. In particular the meteorological variables and the representation of the structure of atmospheric boundary layer can contribute to uncertainties and differences in air pollution predictions. In this study two transport models of different complexity, tested under the same conditions, were applied to reproduce the particulate matter dispersion and ground level concentrations, produced by an elevated coal-fired power plant, located near the coastline in South Italy (Enel BR in Fig.1). The studied area is characterized by the presence of frequent calm winds and a complex sea–land breeze systems, that induced the formation of a thermal internal boundary layer. Such geographical and meteorological features cannot be treated by a simple Gaussian approach. The possibility of using a more complex and sophisticated Lagrangian particle model was therefore considered. In this work the two approaches have been compared in a long and short term simulations. A comparison between modelled and measured concentrations has also been performed.
Figure 1 shows simulation domain, location of source and monitoring stations distribution.



Monitoring Stations	Operator	X_UTM (km)	Y_UTM (km)
1 – Sisri	ARPA	751.07	4501.449
2 – Mesagne	ARPA	737.714	4494.370
3 – San P. Vernotico	ARPA	754.781	4486.042
4 – Torchiarolo	ARPA	758.842	4486.404
5 – San Pancrazio	ARPA	741.444	4478.597
6 – Guagnano	ARPA	751.513	4478.431
7 – Santa Maria Cerrate	ARPA	764.242	4483.446
8 - Giorgilorio	ARPA	766.796	4475.426
9 - Arnesano	ARPA	762.876	4470.79
1E – Villanova Cerano	ENEL	754.878	4499.453
2E – Tuturano	ENEL	750.135	4492.721
3E – San P. Vernotico	ENEL	754.776	4487.166
4E – Torchiarolo	ENEL	758.263	4486.545
5E – Surbo	ENEL	764.807	4478.158
6E – Lendinuso	ENEL	760.838	4489.753

Figure 1: Modelling domain and distribution of monitoring stations.

Tabel1: Models setup

Main characteristics of simulations	
Number of grid cells along X axis	121
Number of grid cells along Y axis	121
Grid spacing ΔX=ΔY	500 m
Annual simulation period	01/01/2007 01:00 to 01/01/2008 00:00
Short term simulation period	19/07/2007 01:00 to 21/07/2007 00:00
Annual PTS emission	673 ton
Annual SO2 emission	10587 ton

Models Description and set-up

ARIA Impact (Aria Technologies, v.1.8) is a Gaussian plume model that takes into account industrial plume rise, deposition, topography and calm wind situations ("puff" formulation). SPRAY (Tinarelli et al, 2000) is a Lagrangian model which simulates the transport, dispersion and deposition of pollutants, emitted from different sources over complex terrain, by following the path of marked fictitious particles in the atmospheric turbulent flow. The model is able to easily take into account complex situations, such as the presence of breeze cycles, strong meteorological inhomogeneities and non-stationary, low wind calm conditions and recirculation.
For the Lagrangian model the meteorology and turbulence were reconstructed by the coupling of SWIFT (Aria Technologies, March 2010) and SURFPRO models on hourly basis, using as input the tridimensional meteorological products supplied, for the year 2007, by the MINNI project (Zanini, 2009, www.minni.org). For the Gaussian model the surface wind and temperature fields were extracted in a virtual station, located near the source.
The coal-fired power plant consists of four stacks, 200m high, grouped together. A monitoring emission system supplied the hourly emissions.
Models set-up is summarized in Table 1.

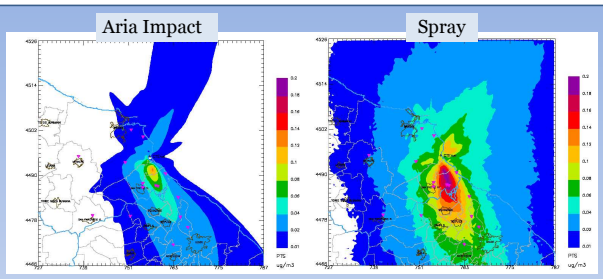


Figure 2: Annual average concentration maps for PTS

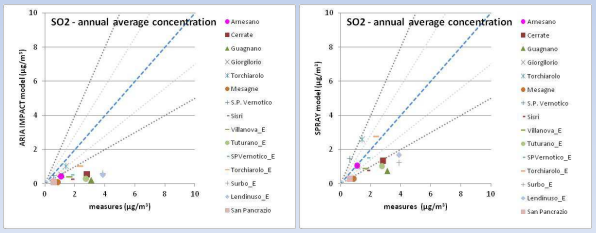


Figure 3: Scatter plots of measured vs predicted yearly mean concentrations of SO2

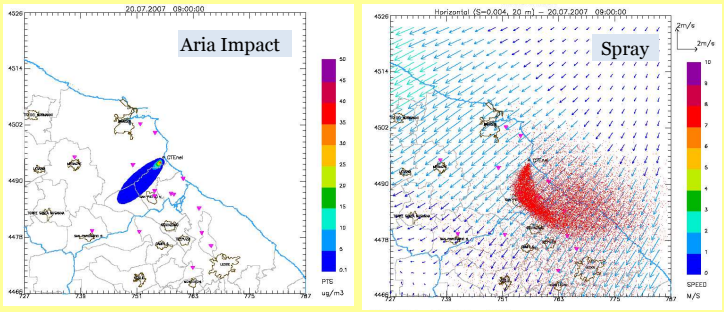


Figure 4: Hourly concentration maps for PTS, for short term simulation (9:00 a.m., 20th July 2007)

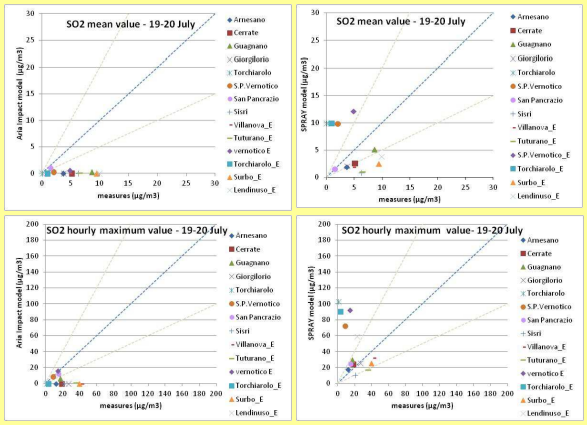


Figure 5: Scatter plots of measured vs predicted mean concentrations and maximum values of SO2 for short term simulation

Results

Figure 2 shows the annual average concentration maps for total particulate matter: even if the general impact area is similar, the Lagrangian representation is more realistic than Gaussian plume model because it is able to reconstruct the convective situations. For this reason the Gaussian model can be useful only for a screening analysis on long period, related to engineering purposes. In order to evaluate the performances of the models, a comparison between modelled and measured concentrations has also been performed, using as coal combustion tracer the SO2 specie (Fig. 3). Aria Impact tends to underestimates the measured concentrations.
The short term simulation, characterized by a breeze system circulation, highlights the differences between the Gaussian and Lagrangian approach (Fig. 4): Aria Impact is not able to reproduce the temporal evolution of breeze system and the related pollutant circulation. This is also evident observing the scatter plots of mean and hourly maximum SO2 concentrations (Fig. 5).

Conclusions

The main difference between the two approaches is the description of the atmospheric turbulence, that strongly affects the simulation results.
The Gaussian plume approach can be a useful tool only for screening analysis on long period, related to engineering purposes.
The Lagrangian approach is recommended for regulatory applications both for long and short term as also established by EPA Guideline on air quality models (Appendix W, http://www.epa.gov/scram001/guidance/guide/appw_03.pdf).