INTEGRATION OF MEASUREMENT AND MODELLING SYSTEMS TO RECONSTRUCT POLLUTION IMPACTS AROUND THE INDUSTRIAL AREA OF PRIOLO (SICILY)

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ABSTRACT
A modelling system potentially able to reproduce the strongly non-homogeneous and non-stationary dispersion patterns at a complex site generated by many industrial emissions has been integrated with the local monitoring network of Priolo (Sicily). The main scope of this work was to both get an overall view of the pollution levels on this particular area, and to eventually separate contributions to the total impact due to different emissions. Annual averages of SO_2 and NO_x due to considered emissions have been reconstructed weighting the impact of short term episodes, chosen through a sampling technique based on the local weather regimes, preliminarly tested using the monitoring network data. Model results have been compared with measurements, showing a good capability to reconstruct both single episodes and the long-term averages.

INTRODUCTION
The region north of Siracusa, southeast Sicily, is a site characterized by the presence of a large industrial area extending for more than 20 km along the Ionian coast. Here a large number of tall stacks routinely emit hot pollutant plumes, whose behaviour is affected by flow regimes influenced by both the sea-land discontinuity and the internal topography, shown in fig 1 representing a 30x30 km^2 map of the considered area

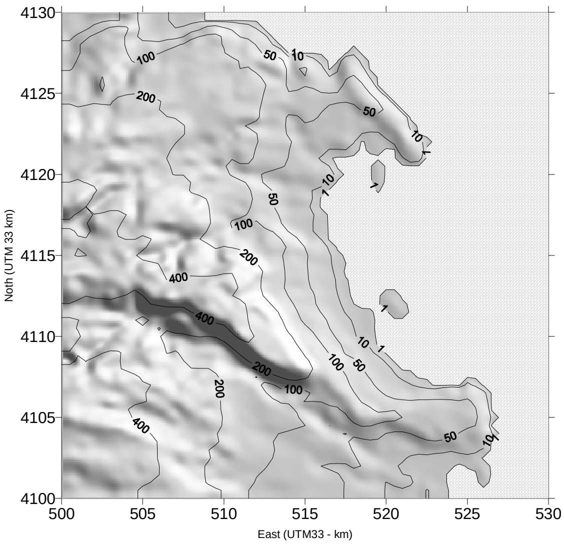

Fig. 1 Map of the horizontal domain. Isolines of topography in meters are represented

In such a complex situation, a modelling approach for the reconstruction of the pollution impact can help for a better comprehension of the dispersion phenomena. Usually, long-term regulatory models assume spatially uniform and stationary in time meteorological information, which has been verified to be far from reality in complex and inhomogeneous (but very common in Italy) sites (Finardi et al. [1]). Land/sea breezes cycles superposed to slope flows are very relevant in this situation to determine pollution episodes. Therefore to describe the atmospheric dispersion of pollutants, a more reliable 3D reconstruction of the complex wind and turbulence fields is claimed. On the other hand, the reconstruction of dispersion for long term assessment have to deal with the evaluation of concentration fields over yearly periods, and some simplification due to the intrinsic limits (memory and CPU) of computers presently in use must be still adopted using complex modelling tools. A method to estimate long term concentration averages based on a limited number of short-term simulations performed by a 3D modelling system has been adopted and verified. This method is based on the classification of local weather regimes determined through the analysis of the in-situ available meteorological and air pollution time series data ([1], [2]). Results obtained set in evidence the synergic role of the modelling approach, able to extend the information given by a local network giving a realistic reconstruction of impact pattern over the interested area, allowing also to obtain some useful information such as the level of contributions to the total pollution of different emissions.

AVAILABLE DATA

A network of three ground level meteorological stations, as depicted in the left panel of Fig. 2, is managed by the local Consortium for the Environmental Protection (CIPA), covering a large part of the considered domain, routinely measuring both wind and temperature on hourly basis. A Sodar and a Rass are also present at the CIPA station located close to the coast, giving hourly vertical profiles of respectively wind and temperature up to about 500m above the ground, allowing a better reconstruction of the breeze cells depth. A total of 28 stacks has been considered (Fig.2 right panel), with different heights ranging from 20m to 160m representing the main emissions of the entire industrial area. SO_2 and NO_x yearly emission rates available from CIPA have been used to build input for dispersion simulations.

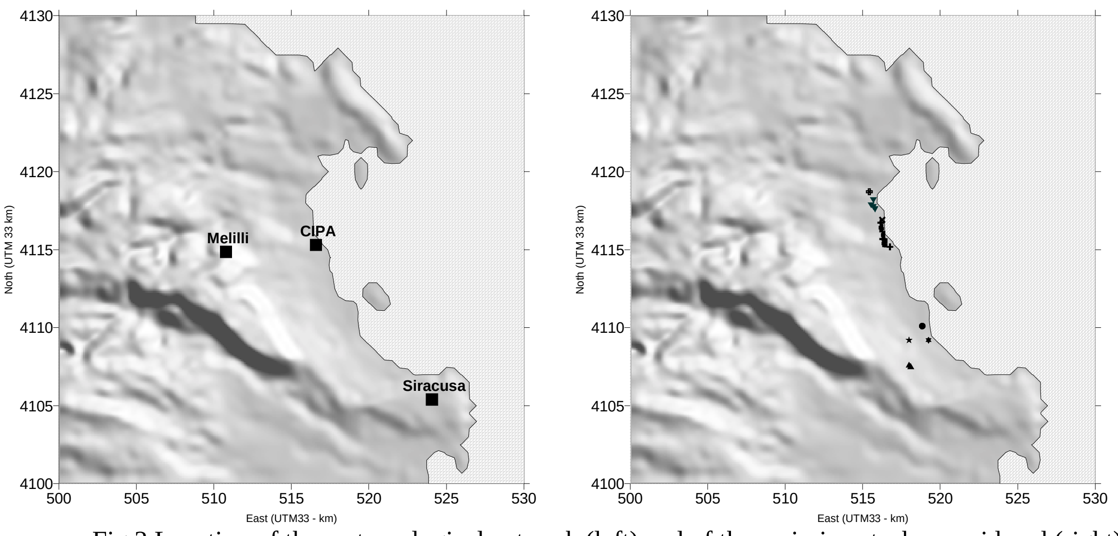

Fig.2 Location of the meteorological network (left) and of the emission stacks considered (right)

LOCAL WEATHER REGIMES CLASSIFICATIONS

Synoptic daily weather classifications, derived from the scheme originally proposed by Borghi and Giugliacci [3], are currently used in Italy for both meteorological and air quality scopes. This classification is mainly based on 12 recurrent weather types, identified by their geopotential patterns at 850 Hpa through a subjective analysis. Being Sicily at the southern limit of the region considered to calibrate this method and in order to take into account recurrent local situations often splitting to different synoptic classes, a local redistribution of weather types has been reconstructed for year 2002. Based mainly on the analysis of local anemometer data, the following classification has been adopted: strong breeze, weak breeze, constant wind, synoptic, coherent, perturbed. 'Breeze' types refer both to the classical presence of a diurnal-nocturnal periodic rotation of wind directions registered by local anemometers, with less stringent requirements (in terms of time duration) in weak conditions. A 'constant wind' is a regime in which the wind direction is persistently from the same sector regardless of the wind speed. The 'synoptic' is a persistent regime in both wind speed and direction. The 'coherent' is a regime showing a progressive and continuous change of wind direction. A 'perturbed' is a situation during which a consistent precipitation, in terms of both duration and intensity, is measured by local pluviometers. Following this new classification, during year 2002 the computed frequency distribution looks as follows:

Strong Breeze	24.1
Weak breeze	36.2
Constant	14.0
Synoptic	7.4
Coherent	0.8
Perturbed	6.8
Unclassified and no data available	10.7

Tab. 1 frequency distribution of local weather regimes (in percent) during year 2002

The classification has shown to be stable, giving similar results during the previous two years 2000 and 2001. An ensemble of five subperiods has been selected for a total of 13 days in order to perform dispersion simulations. They represent a good compromise between two requirements, the need to cover a large percent of the total distribution and a sufficient data availability for 3D simulations. Chosen cases are summarized in the following table:

Case number	Date	Local type
1	11-13/11/2002	*Weak breeze*
2	11-13/01/2002	*Weak breeze*
3	15-18/06/2002	*Strong breeze*
4	6-7/12-2002	*Perturbed*
5	15-17/12/2002	*Constant/Synoptic*

Tab. 2 List of sampled subperiods during year 2002

Missed and unclassified weather regimes of Tab.1 have been redistributed using the relative frequency distribution of the considered classes. In order to verify the choice made, ground level SO_2 concentrations computed using direct measurements along the entire year have been compared to yearly estimations obtained averaging values measured during the sampled periods ad weighting using the relative frequency of each weather type. Fig 3 shows the position of the stations of the local network and the comparison between standard and estimated yearly averages.

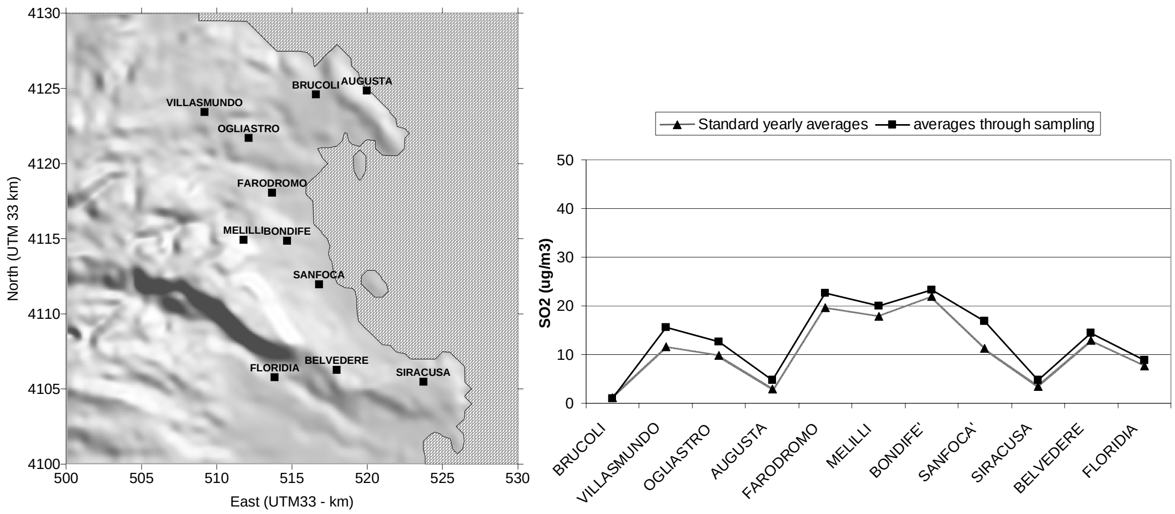

Fig. 3 Position of the local air quality network stations (left) and comparison between directly measured (continuous line, squares) and estimated through a sampling (dotted one, triangles) ground level yearly concentrations of SO_2

Results show a good agreement between directly computed and estimated concentrations, with a slight systematic tendency to overestimations due probably to a sampling biased towards more polluted winter periods.

MODELING SYSTEM AND RESULTS

The 3D wind and temperature fields have been reconstructed at an horizontal resolution of 500m on the computational domain described in Fig. 1 by means of the diagnostic model MINERVE, using local surface measurements, Sodar and Rass data and synoptic meteorological measurements at higher levels. Turbulence scale parameters (u_*, L, H_0, z_i, w_*) have been computed using the meteorological pre-processor SURFPRO that can take into account mountain slopes and shadow projection of the solar radiation. The Lagrangian particle model SPRAY3 [4] was used to describe the atmospheric transport and dispersion of pollutants emitted by the 28 stacks. Ground level concentrations have been estimated from the particle field with the same horizontal resolution used by the meteorological model. All the 5 episodes described in Tab. 2 have been simulated by the modelling suite.

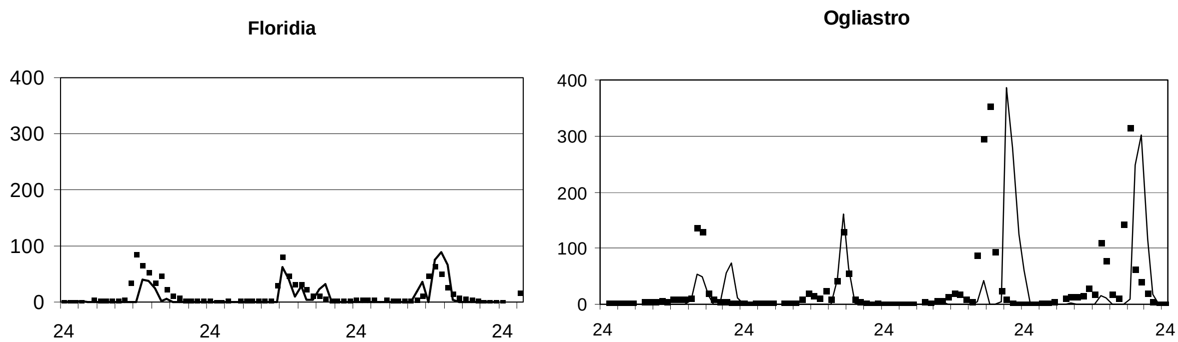

Fig. 4 Comparisons between SO_2 ($\mu g/m^3$) ground level concentration measured (squares) and simulated by SPRAY3 (continuous line) during 11-13/1/2002 episode at Floridia and 15-18/6/2002 episode at Bondifè.

Hourly ground level concentration fields of SO_2 and NO_x have been simulated and compared with observations given by the air quality monitoring network. Fig. 4 illustrates an example referred to the case number 2 and 3 in Tab. 2. The agreement seems quite noticeable.

A 2D field of yearly average concentration for year 2002 has been estimated from the hourly concentration simulated in each episode, weighted on the basis of the occurrence of each local weather condition, as previously described. Fig 6 shows ground level concentration maps of SO_2 (left) and NO_x (right). It is evident the effect of the breeze cycles, which represent more the 60% of the weather types, determining a NW-SE impact pattern. During nighttime, plumes are transported by the land breeze towards the sea, generating higher concentration values due to weaker winds and smaller turbulence. During the day, plumes are transported inland but tends to generate a smaller impact due to the higher turbulent mixing.

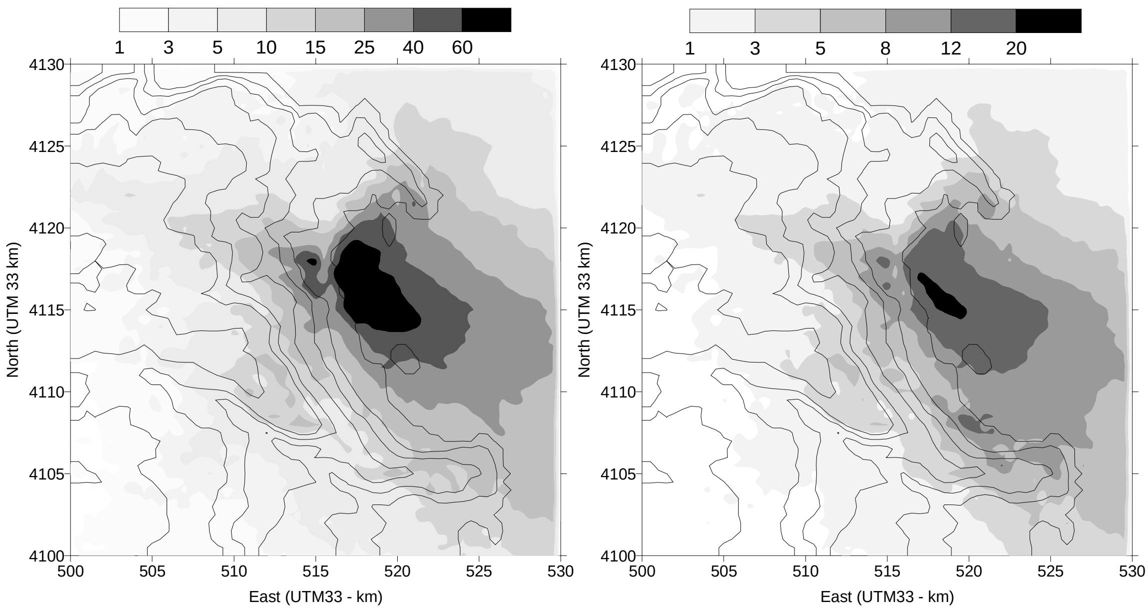

Fig. 6 SO_2 (left) and NO_x (right) ground level yearly concentration fields for year 2002 estimated through sampling. Values in $\mu g/m^3$.

Concentration patterns are also partially confined in the southwestern part of the domain by the topographical barrier that tends to limit the area influenced by the industrial emissions. Yearly concentrations at each station of the air quality network have been also compared with estimations from model simulations extracted at the same point. Results are depicted in Fig. 7 for SO_2. This chemical specie is substantially a tracer of the activity of the industrial site, being the main source of emission. An overall acceptable agreement between estimations and yearly measurements is evident. Stations located in the central sector of the domain (Farodromo, Melilli, Bondifè and SanFocà) closer to the emissions, correctly show larger concentration values, that tends to be locally overestimated at Farodromo. As for measurements, smaller values are computed at southern and northern stations, located far from main emissions. This kind of comparison shows that the local weather classification scheme is a good method to simplify the problem of performing climatological reconstructions in complex situations, allowing a sensible reduction of the computational time (about 1/30 of the time needed for a complete yearly simulation) and results of good quality.

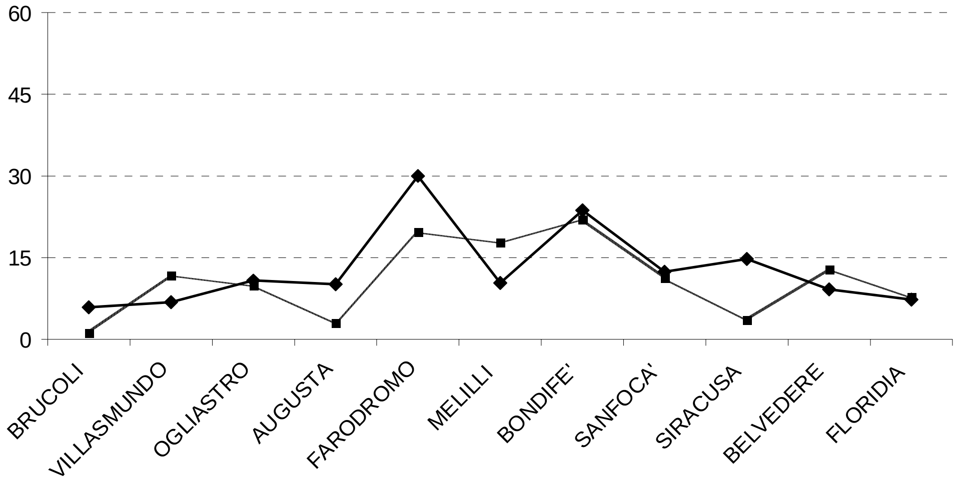

Fig. 7 Comparison of measured (squares) and estimated through simulations (diamonds) SO_2 ground level concentrations at different stations. Values in $\mu g/m^3$.

CONCLUSIONS

A 3D modelling system over complex terrain has been integrated with a measuring network, to reconstruct impact on the air quality of the industrial area of Priolo on climatological basis. To this aim a sampling technique has been developed in order to define a limited number of short term episodes to be simulated, statistically representative of a large amount of the recurrent meteorological situations. This technique allows to strongly reduce the computational time, permitting the use of more sophisticated models able to take into account local complexities. The good agreement between measured and modelled concentration values reached for SO_2, which represent the main emission of the industrial area, show the applicability of the method at a site where also sophisticated and directly usable measurements (Sodar and Rass) are available.

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