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ASSESSING THE IMPACT OF PORT EMISSIONS ON AIR POLLUTION IN GENOA

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Abstract. Maritime transport is of major importance for trade and economic development in the Mediterranean region. On the other hand, many areas of docklands are subjected to strong environmental pressure, thus requiring mitigation measures to reduce the ports impact on environment and people's health. The Interreg Maritime Project AER NOSTRUM participates to the challenge of reducing pollutants emission from port activities and, in particular, from ships. The overall goal is to contribute to the improvement of the air quality in areas overlooking the ports of the cooperation region (Italy-France), while promoting sustainable growth in compliance with the environmental standards prescribed by European laws. As a part of the project, we present some preliminary results of the air quality monitoring and simulations in progress on the port of Genoa.

Keywords: *ship emissions, near-port air quality, smart sensors, PM compositional analysis, CALPUFF simulations.*

INTRODUCTION

Ports play a crucial role as hubs for Mediterranean trade. At the same time, they are sources of air pollution from both the maritime traffic and the related logistic activities. Achieving environmental sustainability in ports is therefore essential for the economy and the air quality in the nearby areas, which are often highly populated. Within the framework of the INTERREG Maritime Italy-France program, the AER NOSTRUM project (http://interreg-maritime.eu/web/aer-nostrum) targets a twofold objective: firstly, to achieve a shared platform for monitoring and simulation data of air pollution; secondly, to assess the benefits of potential emission mitigation strategies. The study area includes several key economic ports of France and Italy; here the focus is on the port of Genoa, one of the busiest European seaport in terms of movements of goods and people.

Monitoring and modelling approaches are combined to assess how the port of Genoa affects the air quality. A low-cost sensor network was implemented to extend the current operational monitoring managed by the regional environmental agency. Despite the intrinsic uncertainty of these sensors, higher spatial density measurements aim to capture the dispersion patterns of pollutants in complex environments (see e.g. Popoola et al., 2019; Karagulian et al., 2019). In addition, two monthly campaigns were designed to estimate particulate matter concentration and sources through filter-based sampling and compositional analyses to feed a positive matrix factorization receptor model (Paatero and Tapper, 1994). An air quality modelling system was used to perform high resolution simulations over the port area. The simulations are ongoing and the results will be evaluated by comparison with observed data and used to investigate mitigation scenarios, such as the impact of the cold ironing on the pollutant levels. For the simulations, a high resolution emission inventory was compiled based on a detailed study of maritime traffic in the port.

MONITORING AIR QUALITY: NEAR-PORT EXPERIMENTAL CAMPAIGN.

Within the AER NOSTRUM project, the air quality monitoring in the port of Genoa is conducted through the use of both traditional and smart, low-cost instruments. The city lies on a narrow and long coastal area, enclosed between the Ligurian Sea and the Apennine Mountains and crossed by few torrential valleys. The infrastructures of the port area stretch all through the city, with potential hazardous health effects.

The selected study area is mainly affected by passenger traffic, being the core of the cruise and ferry sectors. The port’s terminals constitute a critical element with respect to the city, in particular in terms of atmospheric emissions due to both the stationing of ships and the induced vehicular traffic. The existing traditional instrumentation has been enhanced and integrated to collect PM_{10} samples used for source apportionment studies. Regarding low cost instrumentation, the network is equipped with different technologies for real-time monitoring of PM and NO_2 in the air and gravimetric samplers. New sites were identified in very densely urbanized contexts, where it is usually not possible to measure pollutants concentrations using the conventional instrumentation. The smart sensors locations were also chosen according to the extension of urban area in relation to the port, the orography, the local meteorology and the critical receptors present in the area (Figure 1).

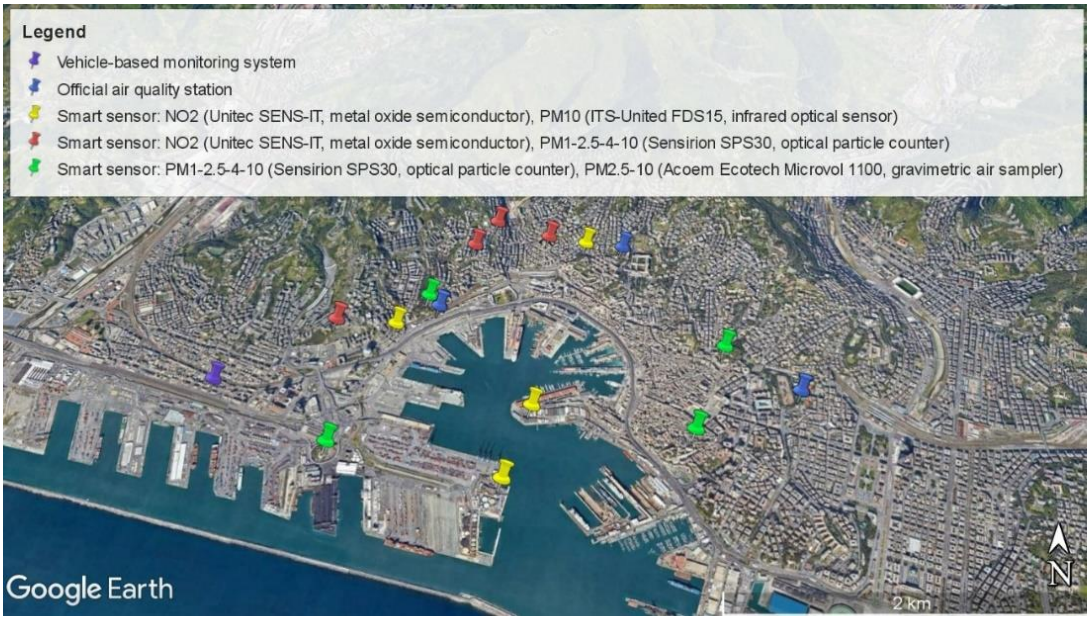

Figure 1. Monitoring network around the port of Genoa (Google Earth Pro V 7.3.4.8642)

Before installation in the proper location, the smart sensors performances require to be tested against reference air quality stations, paying particular attention to the sensitivity to environmental conditions such as temperature, humidity and concentration levels (see e.g. Spinelle et al. 2015, Bisignano et al. 2022). The calibration was carried out at an operational air quality station, under conditions similar to those of port area. An example of the comparison between official and low cost instrumentation data is shown in Figure 2, which refers to a low cost sensor equipped with the thick-film metal oxide semiconductor sensor Sens-IT (Unitec) for NO_2 and with the optical particle counter SPS30 (Sensirion) for PM.

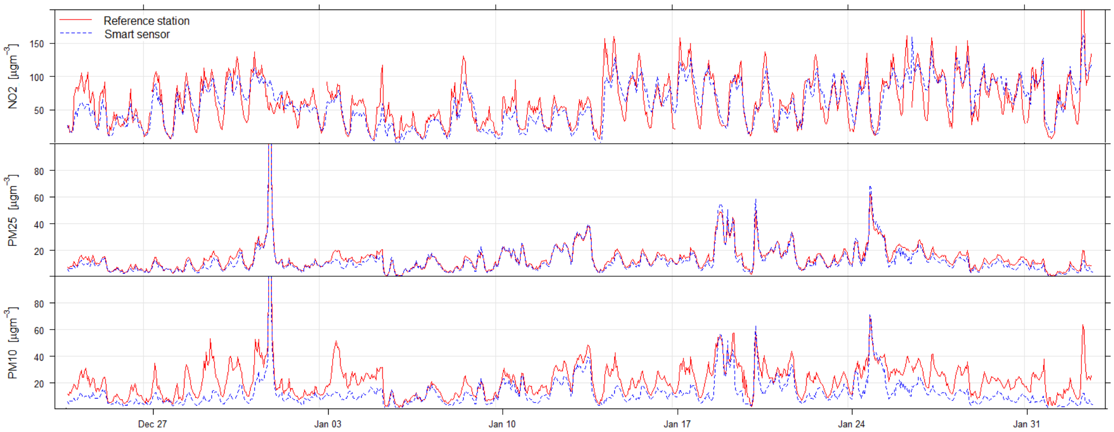

Figure 2. NO_2, $PM_{2.5}$ and PM_{10} time plots from one smart sensor against the reference station data throughout a six weeks' test.

While the smart sensor is able to reproduce reasonably well the NO_2 and $PM_{2.5}$ measurements of the reference station, the PM_{10} levels are underestimated. In order to further analyse performance for PM, Figure 3 shows the scatterplot of the reference measurements against the hourly concentrations collected by the low-cost sensor.

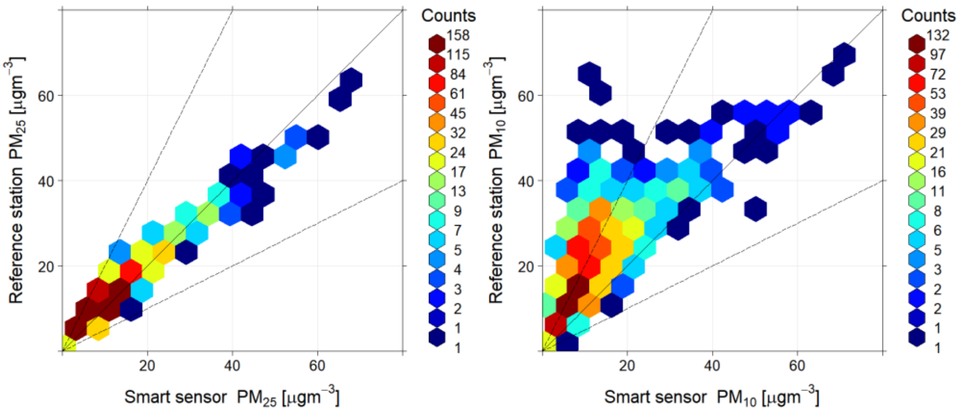

Figure 3. Scatterplots of reference against low-cost sensors data.

The overall performance for $PM_{2.5}$ is satisfactory as almost all the points are within the factor two curves, although the correlation slightly decreases at the lowest values, most likely due to the low accuracy of the sensor. PM_{10} correlation appears to be far less accurate than $PM_{2.5}$ one, highlighting an underestimation by about a factor two with respect to the reference for the majority of the measures. This behaviour is possibly due to the working principle of SPS30. It is able to capture a small fraction of the aerosol particles, upon which statistics are extrapolated. Given the low PM_{10} fraction of typical aerosol, it cannot be measured directly, but it estimated from finer particulates (Sensirion AG, 2020).

The identification of PM emission sources is still a challenging issue and it is a crucial step to design effective mitigation strategies. Within Aer Nostrum project, PM_{10} samples were collected by low-volume samplers (Skypost, TRC TECORA and Digitel DPA14 SEQ LV) designed in conformity with CEN standard. The two sampling sites was located not far from the harbour area, in a residential area close to a road with moderate traffic flow. The instrument was operated on a daily basis during two experimental campaigns: the first from August to September 2021 and the second from April to May 2022, collecting about 160 PM samples on quartz fibre filter membranes (diameter = 47 mm, pore size = 2 μm). The compositional analyses performed by different analytical methods (Bove et al., 2018) allowed a reconstruction of most of the PM mass and a first rough estimation of the mean PM origin (Figure 4) according to Perrino et al. (2009).

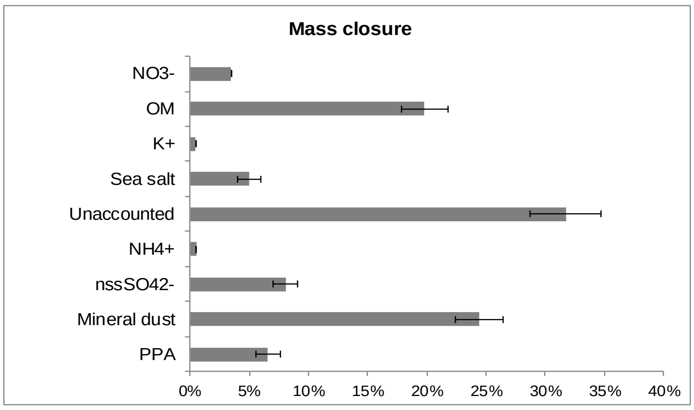

Figure 4. PM_{10} mass closure based on compositional analyses

The sea salt contribution was computed using the sea water composition (Bove et al., 2016): the average was 5 ± 1% of PM_{10}, close to typical values observed in other coastal areas of the Mediterranean basin. Not sea-salt sulphate represented about 94% of total sulphate: they can be summed to nitrate and ammonium to obtain the secondary inorganic aerosol, SIA, which turned out to be 12 ± 1%. The crustal term was calculated by summing the concentration of elements generally associated with mineral dust. Primary anthropogenic aerosol (PPA) was constituted by elemental carbon, which originates directly from combustion emission, plus primary organic carbon; this amount includes organic compounds that condense from the exhausts gases and coat the surface of elemental carbon particles. The contribution of PPA was about 7 ± 1%. Organic aerosol (OM), mostly of secondary origin, was estimated by multiplying the not-primary organic carbon by a conversion factor which estimates the average organic molecular weight per unitary carbon of the atmospheric aerosol. This factor depends on the aerosol composition and thus on the location of the sampling site. Here we used a factor equal to 1.8, since the sampling site is labelled as urban background station (Perrino et al., 2009). The average contribution of organic aerosol (OM) to PM_{10} was 20 ± 2 %.

EMISSION AND DISPERSION MODELLING: PRELIMINARY RESULTS

An air quality modelling system is used to perform high resolution simulations over the port area. Pollutant emission estimates of maritime traffic were calculated in compliance with the EMEP/EEA air pollutant emission inventory guidebook (2019). The ships categories included in the inventory are container, passenger and RoRo cargo. The ships are regarded as point sources while hotelling and as area sources while manoeuvring; in this second case, we identified a standard course between port entrance and docking and the associated emissions were distributed homogeneously over the entire area on the basis of purely geometric considerations. Emission data are used to feed CALMET/CALPUFF (Scire at al., 2000) puff-Gaussian model, which is one of the reference model commonly used in impact assessments. The flow fields required for CALMET initialization are generated by the WRF model (Skamarock and Klemp, 2008) with a resolution of 3.3 km. CALMET/CALPUFF simulations are run with a resolution of 90 m over a 6.3 × 7.2 km^2 domain. Simulations cover the two months' PM_{10} sampling campaign period and they are still ongoing. Examples of CALPUFF results are shown in Figure 5, where PM_{10} and NO_x near-ground hourly concentration are displayed, respectively, in the top and bottom panels. The dispersion patterns highlight how the port emissions may have a large impact on the air quality of the city, depending on the meteorological conditions.

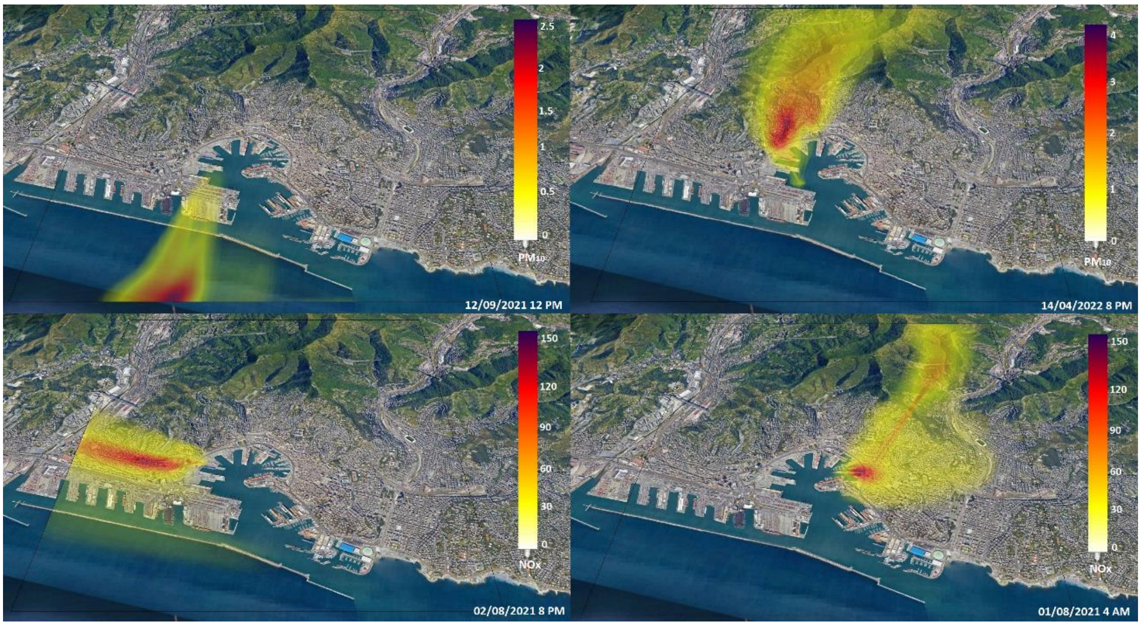

Figure 5. Examples of ground level hourly concentrations calculated by CALPUFF simulations at different times.

FUTURE WORK

The large database collected during the experimental campaign will be used to feed a receptor model through positive matrix factorisation (see e.g. Bove et al 2014).

Concerning modelling, once CALPUFF simulations are done, the first phase will be to verify the modelled PM_{10} and NO_2 concentration fields by comparing simulated and observed values at three reference station. With this aim, background concentrations are substantial source of error. Here we refer to the background as the ambient level of pollution that is not affected by port sources. At the three monitoring sites, background is estimated by means of comparison with data from other air quality stations with the same characteristics, but located outside the port airshed and thus not affected by ships emission.

The second phase will be to assess the benefits of possible emission mitigation strategies, such as the impact of the cold ironing and the use of liquefied natural gas, on the pollutant levels nearby the port. In this stage the background concentrations will be calculated using CHIMERE chemistry-transport model (Menut et al., 2021), online coupled with the WRF model and ran without port emissions.

CONCLUSIONS

The project is aimed at establishing a shared cross-border platform for experimental and modelling data of air pollution in proximity to port areas. This tool is not only intended to gather data from different seaports, but also to establish common methodologies for site surveillance and monitoring, model evaluation and mitigation strategies assessment, based on shared standards and procedures. The final objective is the definition of guidelines for planning the most suitable strategies to mitigate the impact of port emissions on the air quality.

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