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DEVELOPING AIR QUALITY FORECAST AND EVALUATION IN THE CITY OF GENOA AND IN THE LIGURIA REGION (ITALY)

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Abstract: The Laboratory of Environmental Physics at the Physics Department of the University of Genoa is currently involved in both local (the regional project MITA) and Transnational Action Plans projects (namely MED-APICE and ALCOTRA-AERA) addressed to the evaluation of air quality in the Liguria Region (Italy) and in the urban area of the city of Genoa. In particular, at the city level, the focus is on harbour (APICE) and traffic (MITA) emissions. In this framework, an air quality forecasting system is being implemented at DIFI based on previous experience on mesoscale meteorological models (BOLAM, MOLOCH, WRF), diagnostic wind flow models (WINDS) and chemical transport models (SAFE_AIR, BOLCHEM, CAMx, ADMS-Urban). Starting from initial and boundary conditions provided by global models outputs, meteorological fields can be obtained through subsequent nests up to resolutions of a few hundreds of meters. These are processed together with high-resolution emission data extracted from the emission inventory of Liguria Region and with inputs on traffic emissions provided at local level by the Municipality of Genoa. Natural, anthropogenic and biogenic emissions are taken into account, allowing for a complete study. Thus, deposition and concentration values of the main gaseous pollutants (NO_x, SO_x, CO, CH_4, O_3,…) and particulate matter (PM_{10}, $PM_{2.5}$) can be obtained. In order to validate the models, results of the simulations are going to be compared with a great variety of data provided both by the air quality monitoring network managed by the Province of Genoa and by several dedicated field campaigns devoted to particulate matter characterization, carried out directly by our group. In particular, source apportionment studies will be performed by means of both receptor models (as Positive Matrix Factorization and/or Chemical Mass Balance) and specific CTMs routines.

Key words: *Air quality forecast, Chemical Transport Models, harbour emissions, source apportionment*

INTRODUCTION
Liguria is a very complex topography region located in Northwestern Italy and consists of a narrow strip of land bordered by the Ligurian Sea, the Alps and the Apennines mountains, reaching elevations above 2000 m. Most of the population resides along the coast, where the main economic activities are concentrated as well. Environmental concerns are primarily associated with road and maritime transport, whereas industrial emissions are lower, apart from some local hot spots, typically corresponding to coal-fired power plants.

In the framework of both local (the regional project MITA) and Transnational Action Plans projects (MED-APICE and ALCOTRA-AERA), the Laboratory of Environmental Physics at the Department of Physics (DIFI) of the University of Genoa is currently involved in the evaluation of air quality in the Liguria Region and in the urban area of the city of Genoa, by means of numerical simulations as well as dedicated field measurement campaigns. In particular, the APICE (Common Mediterranean strategy and local practical Actions for the mitigation of Port, Industries and Cities Emissions) project is focused on the evaluation of the environmental impact of harbour activities on urban air quality and the definition of long-lasting measures and shared strategies to reduce air pollution in port cities. For the Genoa harbour area, such evaluation will be performed by means of a modelling system currently being implemented at DIFI, based on the mesoscale meteorological model WRF (Skamarock *et al.*, 2008) and the chemical transport model CAMx (ENVIRON, 2010).

The simulated pollutant concentrations will be compared with data provided both by the air quality monitoring network managed by the Province of Genoa and a dedicated campaign devoted to particulate matter characterization, carried out directly by our group. Source apportionment studies will be performed by means of both receptor models (namely Positive Matrix Factorization; Paatero, 1997) and specific CAMx routines. Moreover, simulations at the very local scale can be performed using tools such as ADMS-Urban (Carruthers *et al.*, 2000; Carruthers and Hunt, 2008), once provided with high resolution meteorological and emission data.

Hereafter, the modelling approach will be presented in more details and some preliminary results obtained at the urban scale using ADMS-Urban will be illustrated and discussed.

MODELLING SYSTEM SETUP
The configuration of the air quality modelling system being implemented at DIFI is schematically illustrated in Figure 1. Meteorological fields are obtained by the mesoscale meteorological model WRF (ARW core, Version 3.2), developed and supported by NCAR (National Center for Atmospheric Research) The ARW (Advanced Research WRF) is designed to be a flexible, state-of-the-art atmospheric simulation system that is portable and efficient on available parallel computing platforms and is suitable for use in a broad range of applications across scales ranging from meters to thousands of kilometers (http://www.mmm.ucar.edu/wrf/users/). Initial and boundary conditions needed to drive WRF simulations are provided by the global model GFS, operational at NCEP (National Center for Environmental Prediction).

WRF outputs together with anthropogenic and biogenic emission data are then used as inputs for air quality simulations with CAMx, an Eulerian photochemical dispersion model developed and distributed by ENVIRON that allows for assessments of gaseous and particulate air pollution (ozone, $PM_{2.5}$, PM_{10}, air toxics) over many scales ranging from sub-urban to continental.

Through subsequent nesting procedures as well as the ingestion of higher-resolution emission data, meteorological and pollutant concentration fields are obtained up to resolutions of order of 1 km.

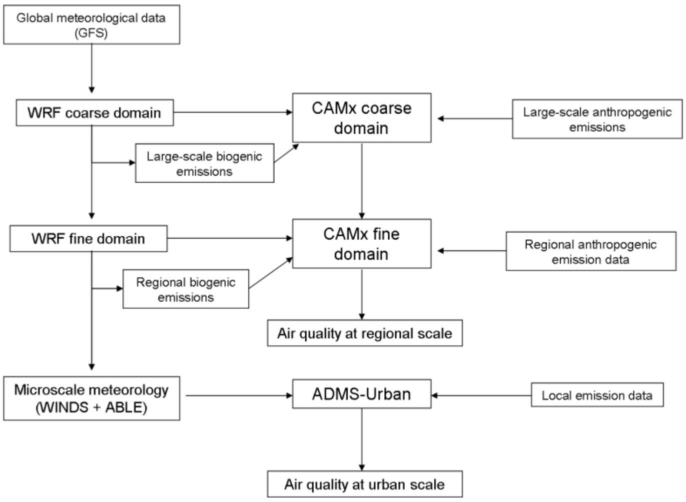

Figure 11. Simplified flow chart of the modelling system.

Mesoscale meteorological fields can be used to drive further simulations with microscale models, so as to get an input to air quality simulations at the urban scale (resolutions of order of 100 m) by means of suitable tools like ADMS-Urban, a new generation Gaussian plume air dispersion model, developed by CERC (http://www.cerc.co.uk/environmental-software/ADMS-model.html). In particular, high resolution wind field simulations are performed using the WINDS code, a diagnostic mass-consistent model being developed by DIFI for several years (Ratto *et al.*, 1990; Burlando *et al.*, 2007; Cassola *et al.*, 2008) whereas boundary layer parameters related to atmospheric stability conditions are calculated through the ABLE code (Georgieva *et al.*, 2002).

Simulation period

The air quality forecasting system described insofar is planned to be made operational every day by late 2011. However, for the purposes of the APICE project, a simulation period has been chosen in order to focus on the situations responsible for the highest pollutant concentrations in the urban area of Genoa.

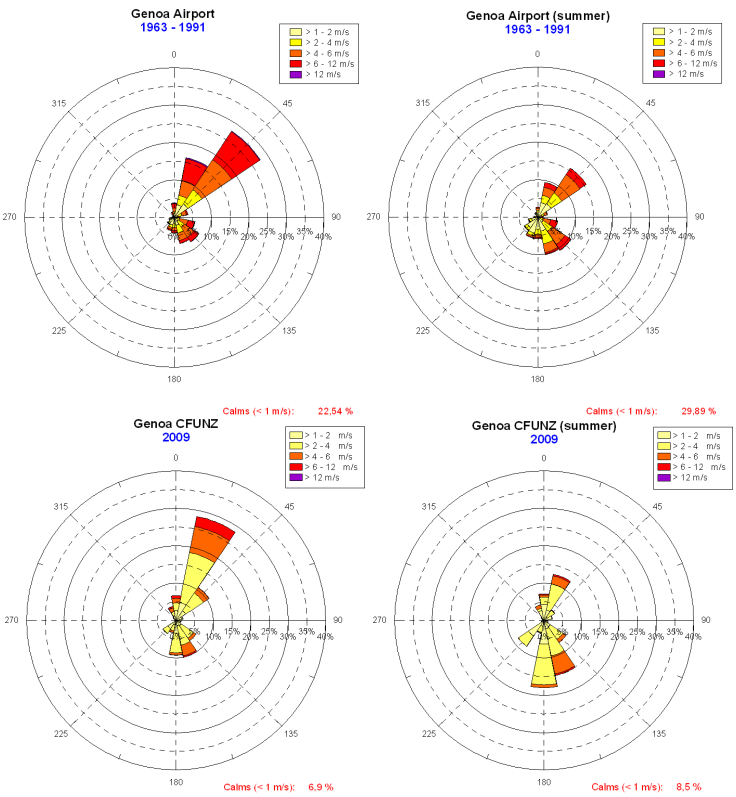

Figure 12. Annual and summer wind roses for Genoa Airport station (top) and Genoa CFUNZ station (bottom).

The analysis of available anemometric measurements from different stations suggests that favourable conditions for the pollutant transport from the harbour area towards the city are mostly encountered during the warm season, due to the onset of diurnal sea breezes, whereas during Autumn and Winter months intense northerly (offshore) winds are prevailing, thus contributing to improve air quality in the urban area. In Figure 2 annual and seasonal wind roses obtained from a long-term time series (Genoa Airport station, in the western part of the harbour area) and a shorter one (Genoa CFUNZ station, close to the eastern edge of the harbour area) are reported. Despite some differences in the distribution of occurrence frequencies of wind speed and directions, essentially due to local effects associated with the complexity of the surrounding terrain, both stations are characterized by similar wind conditions, with a significant increase of S-SE flows during summer with respect to the rest of the year, when N-NE winds are predominant.

Moreover, during summer months harbour emissions are significantly higher because of the increase of passenger traffic. Following these considerations, we decided to run the models for the period spanning from May to September 2011. In the meantime, an intensive measurement campaign is going on and the collected data will serve as a basis for model validation and for source apportionment studies using receptor models.

SOME PRELIMINARY RESULTS

The microscale atmospheric dispersion code ADMS-Urban has been used as a first tool for the evaluation of the main impact area of the harbour activities emissions, aimed at the identification of the sites to be considered for the monitoring campaign and for the model validation. Considering both the statistics relative to the wind intensity and direction presented above and the location of the harbour with respect to the urban area, we have performed some test runs with arbitrary values of NO_x emission rates from sources located in the harbour area. In Figure 3 we show the most significant results of these test cases and the location of the three sampling sites (Multedo, Bolzaneto and c.so Firenze) which has been chosen, among the equipped cabins of the municipal air quality monitoring network, as the most relevant in order to evaluate the impact of the harbour emissions on the city area.

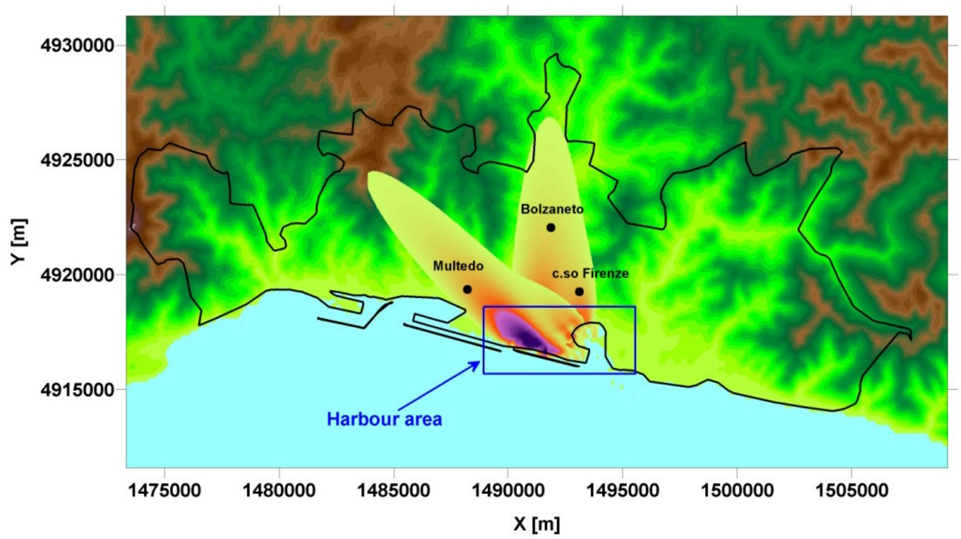

Figure 13. Test simulations with ADMS-Urban for the evaluation of the impact of harbour activities emissions on the urban area. Two cases are reported: one with SE wind of 5 ms^{-1} intensity and one with S wind of 5 ms^{-1} intensity. The pollutant simulated is NO_x with arbitrary emission rates. The black line indicates the administrative boundaries of the city of Genoa, the blue rectangle indicates the most emissive harbour area.

In order to have a more complete overview on the air quality in the city of Genoa, with the analysis of seasonal trends and of the effects of different and typical meteorological scenarios, we have performed a very preliminary study, in collaboration with the Genoa municipality and with the local environmental protection agency ARPAL. With a simpler and different modelling chain with respect to the one described before (which is now under construction) we have then simulated a one-year period (2008), allowing for some first climatological and statistical analysis. Meteorological fields provided by the mesocale model MOLOCH (operational in ARPAL, http://www.isac.cnr.it/dinamica/moloch/index.html) are used to initialize the microscale codes WINDS and ABLE to get high resolution meteorological fields in the domain area. The dispersion code used is ADMS-Urban with emission inputs extracted from the regional inventory (grid and point sources) and from the local inventory of the Genoa municipality (road sources). Emissions due to the harbour activities have been extracted from the regional inventory and then treated as grid sources (defined in a 1-km spatial resolution grid) with a single temporal profile applied for all the source area. This aspect, together with the oversimplified chemistry reaction scheme in ADMS and the missing treatment of accurate boundary conditions from a large scale simulation, has to be considered a limitation in the description of the studied area, in particular when the main goal of the APICE project is taken into account, then remarking the preliminary character of the results shown.

As a first result obtained in this study we present here the simulations of NO_x dispersion in the Genoa urban area in two different emissive scenarios, i.e. with and without taking into account the harbour area emissions. In both cases we have simulated the whole 2008 period and then obtained 8784 hourly concentrations values which have then been averaged giving the mean values reported in the two maps below (Figure 4). The effect related to the presence of harbour emissions can be clearly seen when the two maps are compared, confirming the main role played by harbour activities as emission sources which have a strong impact on the Genoa urban area and which can be identified as a critical point in the determination of the air quality of the city.

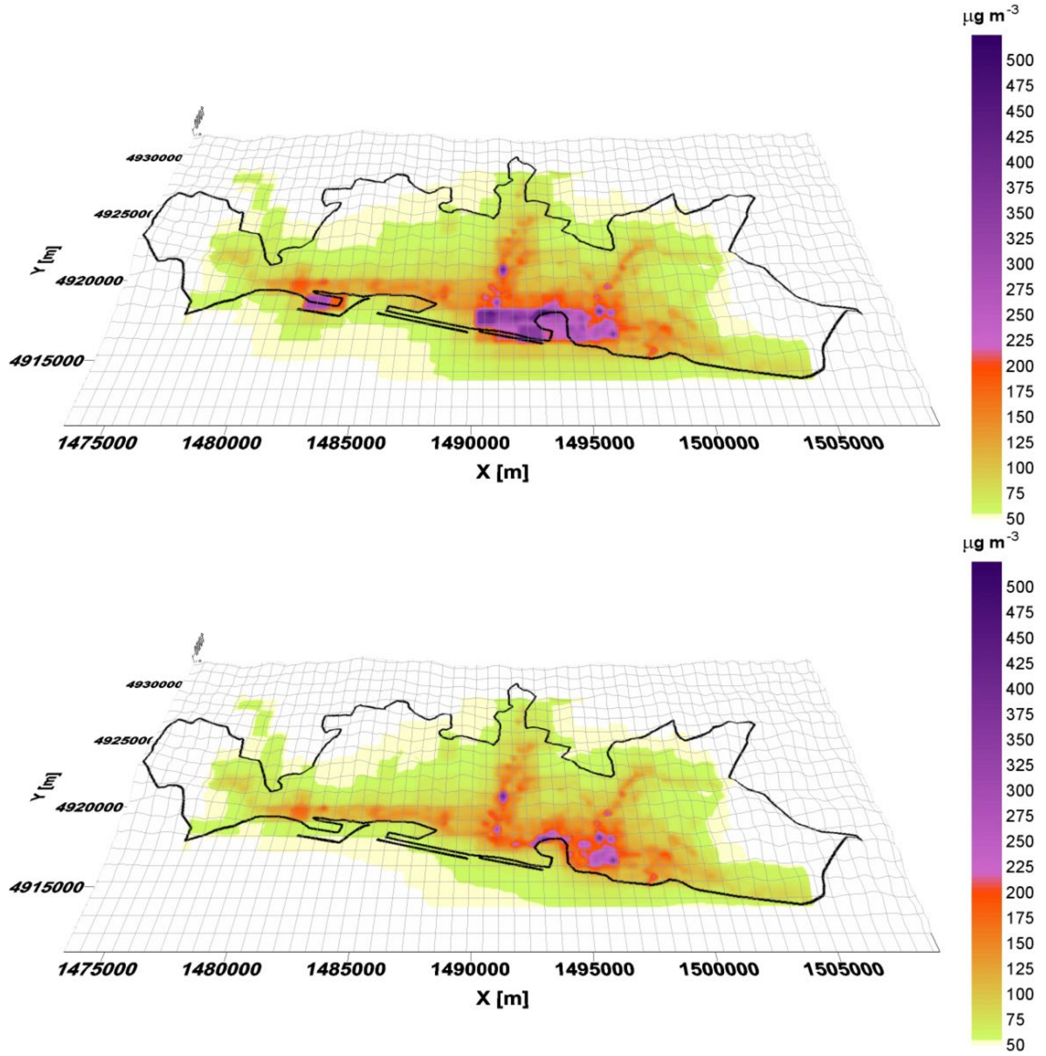

Figure 14. Concentration maps of NO_x at 2m above the ground level for the year 2008, with harbour activities emissions (top) and without harbour activities emissions (bottom). Reported values are mean hourly concentrations obtained by the average of hourly values simulated for the whole period of simulation. Concentration values should be compared with the limit of 200 μg m^{-3} fixed by European directive on air quality 2008/50.

Another aspect which has been analyzed giving interesting results is the effect of meteorology, and in particular the effect of wind, on the dispersion of pollutants. We report in Figure 5 the results obtained with the simulations of two summer days (July 30^{th} and July 20^{th}), and we show both the wind fields given by the meteorological pre-processor (left column) and the NO_x concentration values calculated by the dispersion model (right column).

In the first case (July 30^{th}) the wind intensity is quite low, the concentration values (mainly in the harbour area) are high in the proximity of emission sources but the spread over the whole domain is not so high. The situation changes in the second case (July 20^{th}) when the wind intensity is higher and then the pollutants can be locally washed out but at the same time are transported farther away from the emission sources location (this can be seen in particular on the concentration level in the harbour area), having an impact on a wider urban area. The effects of wind transport related also to wind direction have to be considered together with the domain geometry. In this case we have SE winds along all the city area and then the pollutant emissions, in particular from harbour activities which represent the main sources, affect the air quality of the NW side of the domain which is mainly urban highly populated area, while the southerly side of the domain (which is mainly sea) presents lower NO_x concentrations.

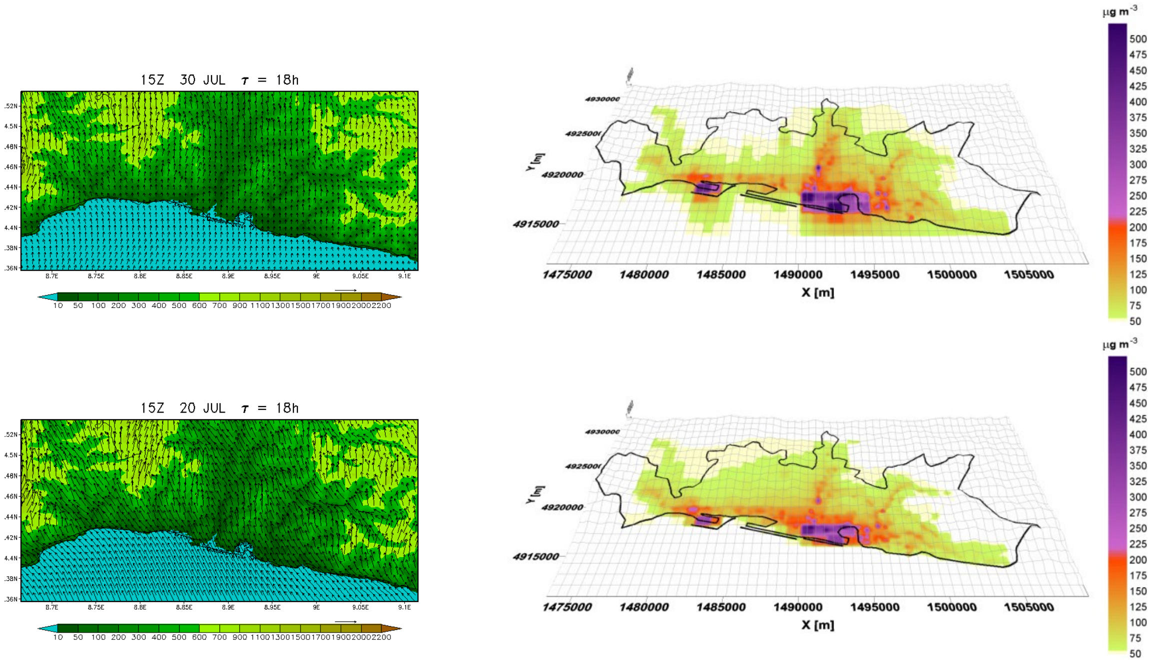

Figure 15. Results of the simulations for two summer days, July 30th (top) and July 20th (bottom). In the left column we report the maps with topography and 10 m wind fields obtained by the meteorological pre-processor for the afternoon time. In the right column we report the hourly mean concentration values at 2m above the ground level of NO_x averaged on the whole day.

CONCLUSIONS

We have shown here some preliminary results obtained by simulations of air quality and pollutant dispersion performed by a first version of our modelling chain. Nevertheless, even with such simplified version, we have been able to identify the most critical and likely meteorological scenarios to be considered in the evaluation of the air quality of the city of Genoa. We focused our attention in particular on the impact of harbour emission on the urban area (as a goal of the APICE project), showing that harbour activities play a prominent role among all the other anthropogenic sources and indicating which are the most affected areas. A more complete and accurate modelling system is under construction, which will be able to take into account both more sophisticated chemistry mechanism schemes and the effects of large scale transport of pollutants, and allowing for the analysis of air quality from the mesoscale (up to an European domain) to the microscale (with simulations performed around the hot spots individuated by larger scale models).

ACKNOWLEDGEMENTS

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