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IMPACT ASSESSMENT ON AIR QUALITY IN LOMBARDY OF THE LIMITATIONS FOR CONTRASTING THE DIFFUSION OF COVID-19

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Abstract: In this paper, ARPA Lombardy presents the simulation results and a preliminary impact assesment on air quality due to the introduction of limitation and social distancing rules for contrasting the diffusion of COVID-19 disease. A specific data flux and methodology have been developed on the base of the most recent emission inventory available for the Lombardy region and algorithms, ad hoc built up for the study, to estimate the primary emission variations of the main atmospheric pollutant, potentially affected by the anti-COVID rules. Two emission scenarios have been identified: "BAU", defined as business as usual, and "COVID", defined as the situation expected during the period. The main emission estimates on a daily base have been used as input in the chemical transport model FARM for evaluating the impact of lockdown on air quality in Lombardy. Simulated data have been also assimilated with measurements in 2020 and measured data in the three previous years 2017-2019.

Key words: *Model simulation, air quality , emissions reduction, COVID*

INTRODUCTION

The aim of this work is to evaluate the impact on air quality due to the introduction of measures for contrasting the diffusion of COVID-19 disease.

This preliminary study describes the modelling system and the approach implemented and the results obtained about atmospheric concentration of the main pollutants: NO_2, O_3 and PM_{10} comparing the impact of two different emission scenarios. The first refers to the emissions estimated business as usual (BAU) and represents the emissive situation that would have occurred in a non-COVID context. The second one, lockdown scenario (COVID), is based the emissive estimates occurred during the period characterized by anti-COVID measures. The simulations here reported refer to the period 15 March - 03 May 2020 and to the territory of Lombardy region, even the emission estimates have covered a larger period on the months of lockdown (ARPA Lombardia, 2020).

MATHERIALS AND METHODS

The informative base for the emission estimates in Lombardy is the more recent edition available at the time of starting this study obtained by INEMAR database referring to 2017 (INEMAR ARPA Lombardy, 2020). The definition of the BAU scenario starts from these results. The regional emission inventory gives an estimation of the primary emitted pollutant on year base. The evolution of actions to contrast the COVID disease spreading during the month of March and April evolves in order of days and the average temperatures, connected to the heating demand, also shows daily changes. These factors have suggested an approach on a daily base for emission estimates and air quality simulations.

As reported in many activities connected to the use of emission inventories in air quality modelling (Crippa et al. 2020), the emissions into the atmosphere must be evaluated by their temporal variations. By a collection of surrogate variables or proxies and indicators, the daily emission estimates for the BAU scenario are calculated by the following:

$$E_{2020,pollutant,activity,fuel,day} = E_{2017,pollutant,activity,fuel,year} \times A_{2020,day}/A_{2017,year} \quad (1)$$

For giving an example, the daily emissions from the heating sector are calculated by the ratio between the heating degree day (HDD) for a specific day and the annual HDD for the reference year of the emission

inventory. In COVID scenario regional emissions are obtained by applying to INEMAR data, reduction or increase coefficients due to the introduction of measures contrasting the diffusion of COVID disease. Regional daily emissions reduction is quantified by assuming a linear relationship between the activity A, representing a specific emissive source, and the related emission referring to the year 2017: in particular, emissions for each day of 2020 are calculated starting from 2017 annual emissions and by applying the ratio between the daily value of the indicator and its annual value referred to 2017. The emission scenario calculation has been performed obtaining a dataset of the emission inventory on daily base for the main pollutants, for all categories and fuels estimated in the reference year for both the scenarios: BAU and COVID. Outside Lombardy territory, emission dataset of the PREPAIR Project (PREPAIR, LIFE15 IPE IT013, http://www.lifeprepair.eu/wp-content/uploads/2017/06/Emissions-dataset_final-report.pdf) based on 2013 is used on municipal scale, the national emission inventory ISPRA, update to 2010, gives emissions related to neighbouring Italian regions on provincial scale and EMEP 2012 provides Swiss emissions.
The air quality simulation on emission scenarios BAU and COVID have been performed by the modelling system implemented to evaluate impacts on air quality: ARIA Regional (Silibello et al., 2008), developed by AriaNET srl and applied by ARPA Lombardy. The core of the system is the eulerian model FARM (http://www.farm-model.org/), which allows to describe the main chemical-physical processes of primary and secondary pollutants formation and removal and the process of transport and dispersion of pollutants due to wind and atmospheric mixing. The main other components of the system are:

- processors for the organization of meteorological measures;
- the diagnostic model SWIFT that produces wind field, pressure, temperature and humidity data. Meteorological data are obtained by assimilating the hourly parameters, from a subset of stations of the local network and from radio sounding carried out in Linate, to meteorological fields produced by the European Centre for Medium-Range Weather Forecast, ECMWF (https://www.ecmwf.int/);
- SurfPRO (Silibello et al., 2007), the model implemented to define atmospheric turbulence parameters, dry deposition rate of gaseous pollutants and closing constants of eulerian equations;
- the EMission MAnager (http://www.aria -net.it/it/prodotti/emission-manager/), which processes emission inventory and prepares emissive data to give in input to FARM;
- modules that prepare initial and boundary conditions to FARM model, based on regional air quality database and on field simulated on continental scale by CHIMERE model (https://www.lmd.polytechnique.fr/chimere/).

The modelling system was applied over a computational domain covering an area of 236 x 244 km^2 set on Lombardy Region, with a horizontal resolution of 4 km and 13 terrain-following vertical levels.

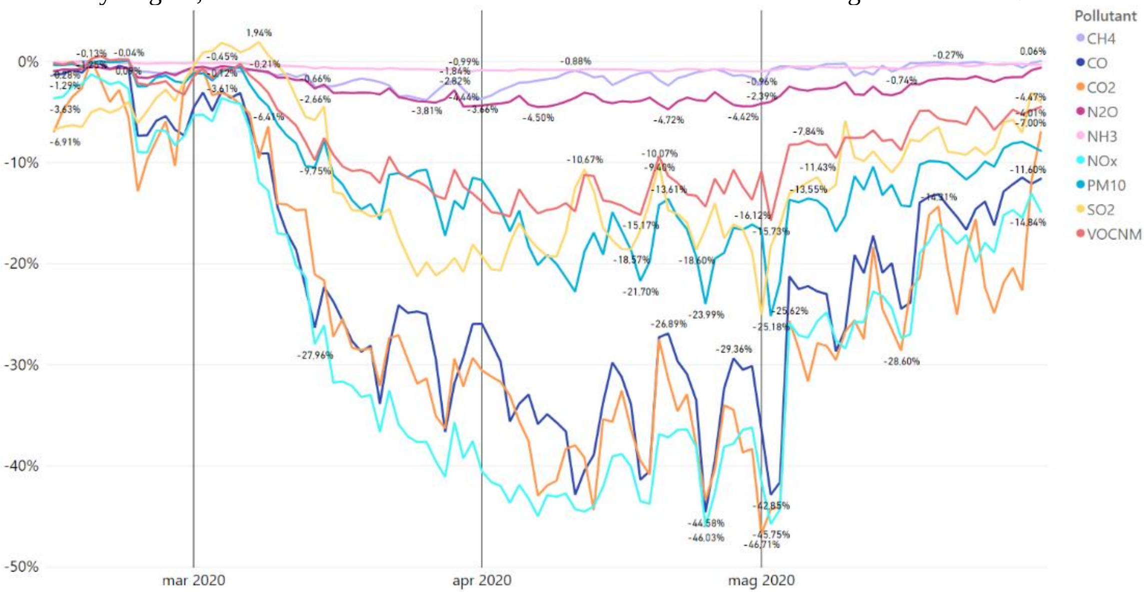

Figure 1. Daily Lombardy emission trends for primary emitted pollutants, calculated as (COVID-BAU)/BAU

RESULTS AND DISCUSSION

Figure 1 shows the main emission trends estimated across the emission scenarios: BAU and COVID. The data on emission estimates are the input of the simulation performed by the eulerian model FARM.
Maps in **Figure 2** illustrate differences between concentrations in COVID scenario and concentrations in business as usual (BAU) scenario. Concentrations are average values on the simulation period 15/03/2020 – 03/05/2020 for each point grid of the domain on Lombardy. As clearly shown by the maps in **Figure 2**, reduction in concentration is higher for NO2 and very poor for atmospheric PM10. As a matter, the changes in emission share for the primary pollutants reasonably cause an increase of simulated tropospheric concentration of ozone.

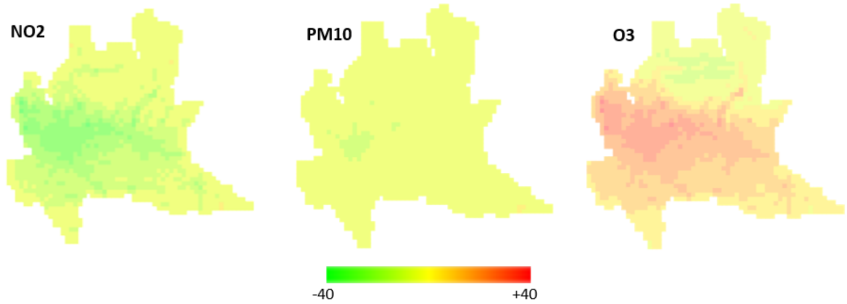

Figure 2. Concentration difference between COVID and BAU scenarios for NO2 and O3 in ppb and PM10 in µg m^{-3}.

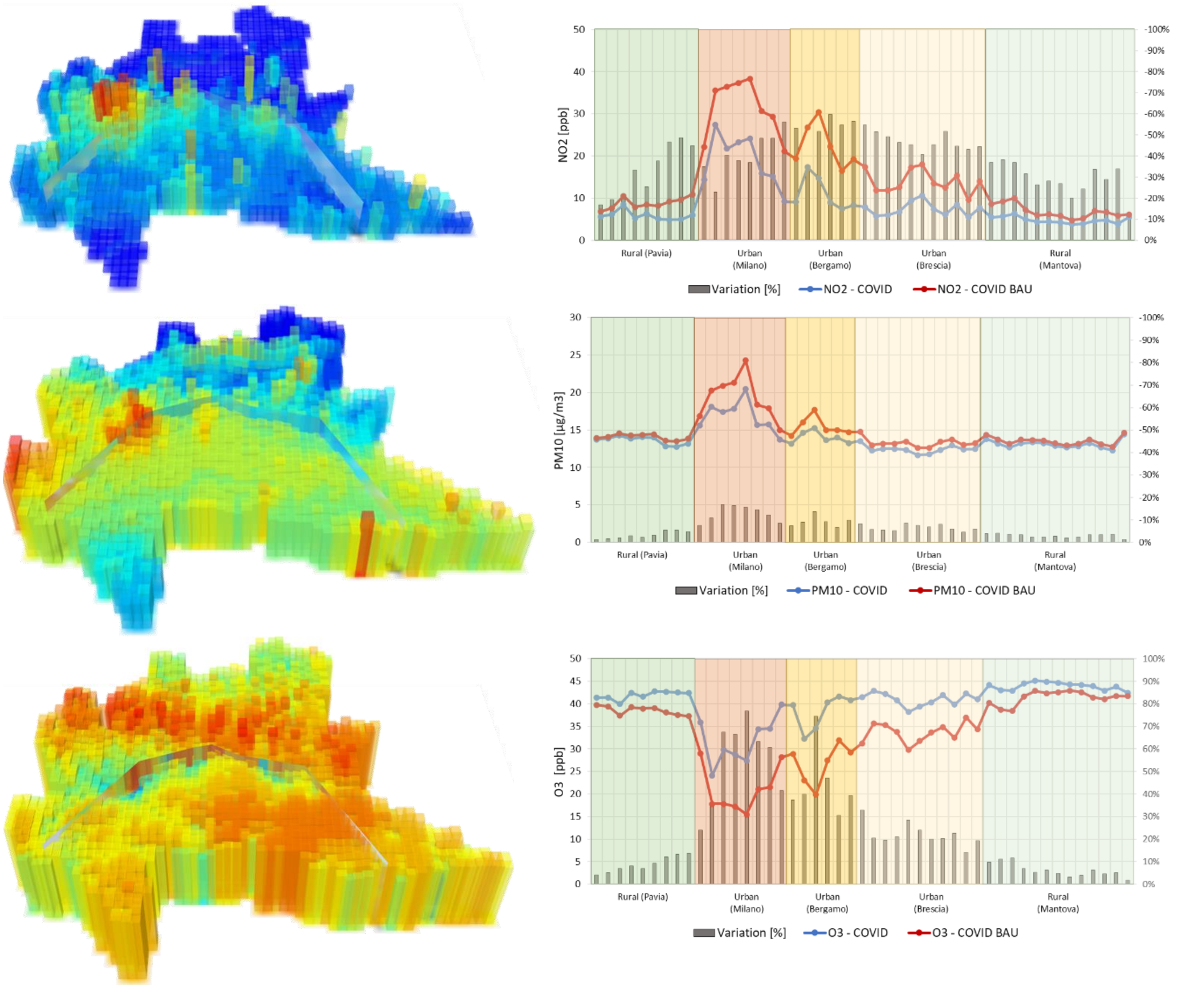

Figure 3. Concentration difference between COVID and BAU scenarios.

In **Figure 3**, the 3D representation of average concentration simulated in the COVID scenario is combined with a slice extraction of the simulation results for the different pollutants. The extraction of data proceeds along the line depicted and on the right plots the simulated data for COVID and BAU scenarios are compared. Box-plot in **Figure 4** represents concentrations distribution measured during lockdown ($M_{lockdown}$, white box), average concentration measured in the same period of the previous three year 2017-2019 (texture fill box) and concentration distribution referring to BAU scenario (M_{BAU}, striped box). The latter is obtained by applying the following equation, where C_{BAU} and $C_{lockdown}$ are concentrations referring to, respectively, BAU and COVID scenario provided as output by modelling system.

$$M_{BAU} = M_{COVID} + M_{COVID} \times (C_{BAU} - C_{COVID})/C_{COVID} \quad (2)$$

Data refer to areas and agglomerations identified in the Lombardy region by air quality zoning according to law (D.G.R. n. 2605, 30/11/2011).

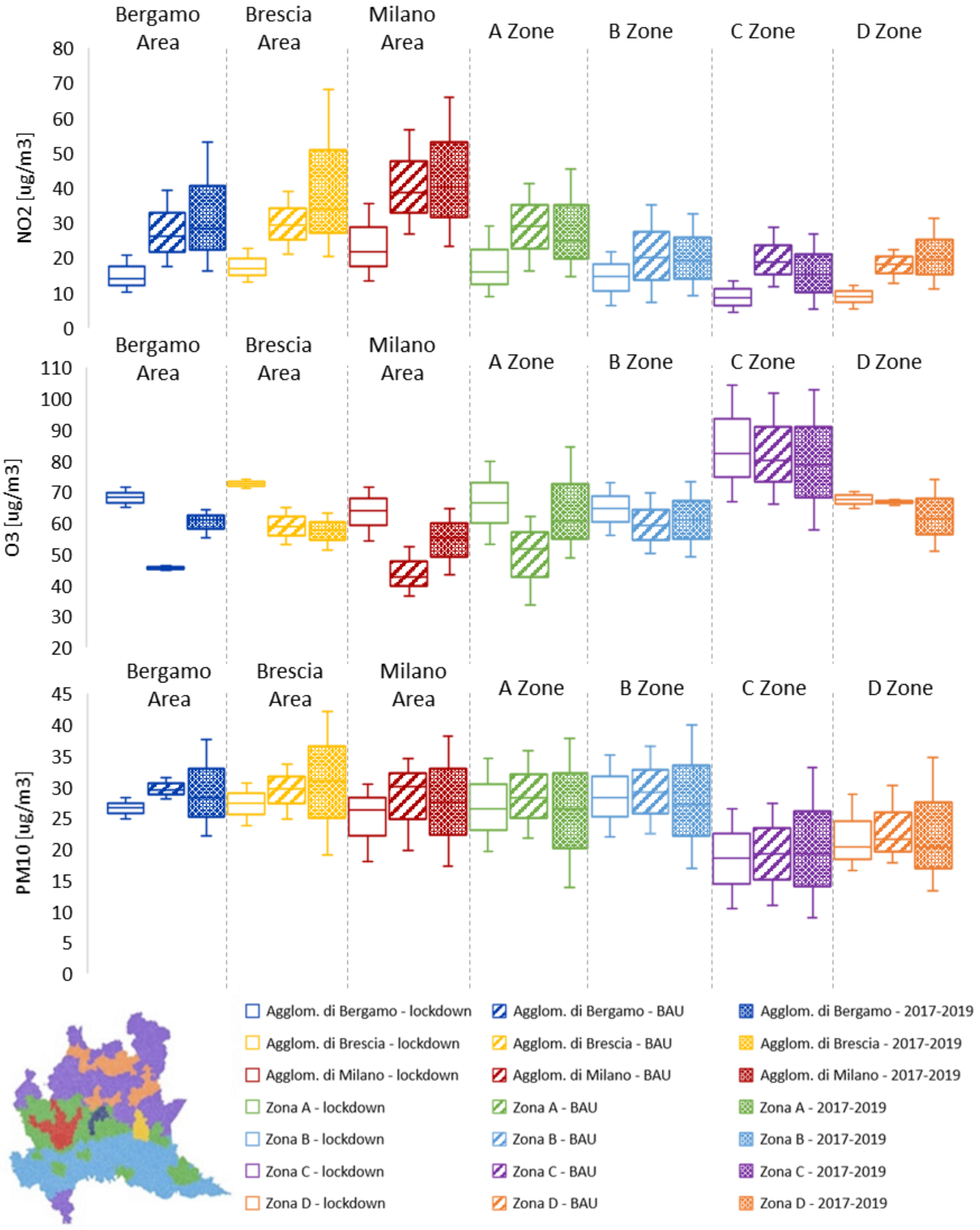

Figure 4. Concentration of main pollutants in different areas of Lombardy, comparison between assimilated data to measurements and measured data in the three previous years 2017-2019 (ARPA Lombardy, 2020).

Results in **Figure 2**, **3** and **4** illustrates that NO_2 concentrations decrease significantly during lockdown period compared to BAU scenario and to data measured in the corresponding period of the previous three-year. O_3 shows an opposite trend, since its concentrations increase especially in urbanized areas, while variation in PM_{10} concentrations is not very significant. Values simulated in BAU scenario referring to PM_{10} and NO_2 align better with the ones measured in the previous three year. This phenomenon is due to the combination of hybrid nature of two pollutants (that are both primary and secondary) and of size of calculation grid cells, which allows a better representation of hybrid pollutants deriving from a multiplicity of distributed emissive sources. Furthermore, results related to O_3 show a model sensitivity to NO_2 concentrations in most urbanized and industrialized areas, where values estimated in BAU scenario are lower than data measured in the previous three years; however, these outcomes are affected by meteorology of simulation period and by the method used to provide emissions as input to the model. The results obtained by implementing the modelling system previously described are highly influenced by meteorology characterizing simulation period. The meteorological variability typical of springtime (the lockdown period) makes the comparison between different years difficult and causes a lower predictive ability of the model in air quality simulations. The meteorological characterization of the period is well described in Project LIFE PREPAIR – LIFE15 IPE IT013 (Progetto PREPAIR, 2020). As a first approximation, about PM_{10} components, models outputs do not highlight variations between ammonium sulphate and nitrate masses estimated by different scenarios; while total carbon decreases because of reduction in elementary carbon emission from road traffic. Variations in pollutants concentrations between COVID and BAU scenarios can be attribute to emissions reduction: between 15 February and 31 May 2020, NO_x and primary PM_{10} show an overall reduction respectively of 32% and 14%. The main driver of this trend is road traffic.

CONCLUSION

The modelling system described in this work and applied by ARPA Lombardy allows to estimate impacts on air quality of measures introduced to contrast the diffusion of COVID-19 disease. The described approach encompasses both the CTM modelling chain (ARIA Regional) and the emission modelling tools implemented in INEMAR. By the experience of ARPA Lombardy, the integration of these two suites has confirmed how the interaction between emission inventories development and CTM application is relevant to give fast responses to this event. NO_2 concentrations reduction has shown quite a linear response to NO_x emissions reduction, while for O_3 opposite evolution is detected: decreasing in emissions corresponds to an increasing in concentrations. PM_{10} atmospheric concentrations simulated by the model, confirm its nature of primary and secondary pollutant, showing quite an independent trend respect to the corresponding primary emission reduction. However, these results are affected by the sensibility of modelling simulation to input data.

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