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MODELLING COVID19 LOCKDOWN IMPACT ON THE ITALIAN LOMBARDY REGION AIR QUALITY: ASSESSING OF TWO METHODS

Andrea Piccoli[1], Valentina Agresti[2], Elena Chianese[3], Guido Pirovano[2], Angelo Riccio[3], Giovanni Lonati[1]

[1]Department of Civil and Environmental Engineering, Politecnico di Milano, Milano, Italy
[2]Sustainable Development and Energy Sources Department, RSE Spa, Milano, Italy
[3]Department of Applied Science and Technology, University of Naples "Parthenope", Naples, Italy

Abstract: The Lombardy region was one of the European areas earliest affected by the Coronavirus in 2020, as well as the first area where lockdown measures were enforced. This study aims to investigate the impact of lockdown on air quality for this region of Northern Italy, analyzing a 2 months period. In this work, CAMx and WRF models were used in order to estimate NO_2, PM_{10} and $PM_{2.5}$ concentrations both during the lockdown and in a business as usual (BAU) situation. NO2, PM10 and PM2.5 concentrations both during the lockdown and in a business as usual (BAU) situation. Model simulations considered two lockdown scenarios, based on different approaches for the assessment of road traffic emissions reduction, in comparison with BAU scenario. The first scenario used emission reduction coefficients computed by the local agency for environmental protection, while the second was based on mobile phone data. We aim to understand whether using these latter data as a proxy could be a promising method for mobility scenario studies.The lockdown offers the opportunity to validate, for the first time ever, modelled scenarios of reduced mobility, proving the reliability of both methods and modelling chain. We take this opportunity by assessing a new approach to support urban mobility, based on a crowdsourcing solution.

Key words: *COVID-19; road traffic; Po Valley; air polllution; air quality; emission reduction.*

INTRODUCTION

The Lombardy region was one of the earliest areas affected by the Coronavirus pandemic in Europe as well as the first area in Italy where lockdown measures were introduced. Here the first measures were imposed on 24th February 2020 and a national lockdown was declared from March 9th. This study aims to assess the impact of COVID-19 pandemic lockdown strong road traffic reduction on Lombardy air quality during the months of March and April 2020. Similar studies are available in literature, most of them are based on the comparison of 2020 measured pollutant concentrations respect to previous years (Sicard, et al., 2020, Bao & Zhang, 2020, Collivignarelli, et al., 2020). Nevertheless, such assessment of concentration variation is affected by a meteorological bias. For this reason a modelling approach was used in this study, allowing to simulate both the atmospheric concentration of pollutants during the lockdown and in a business as usual (BAU) condition. We modelled road traffic reduction, related emissions and concentrations during the lockdown as a real-time scenario study and we were able to validate them with observed data. This allowed to validate different dataset and methods to simulate the exceptional condition of reduced mobility. Two ways to simulate reduced road traffic emissions were compared: the first one based reduction emission coefficients found in literature and the other one based on mobility trend data. Pros and cons of both methods are highlighted. In this work, both modelling and scenario set-up are presented in Methods section, while results and conclusion are presented in the last paragraph.

METHODS

Modelling set-up and input data

A modelling chain composed of the Weather Regional Forecast (WRF) model (Skamarock, et al., 2008) and the Comprehensive Air Quality Model with Extensions (CAMx) model version 6.30 (Ramboll Environ, 2016) was used for the simulation of meteorological variables and the atmospheric concentration of NO_2, PM_{10} and $PM_{2.5}$ of Lombardy. Both models were applied over a computational domain with a spatial resolution of 4km (**Figure 1**). Further details on CAMx and WRF configuration can be found in Piccoli, et al., 2020.

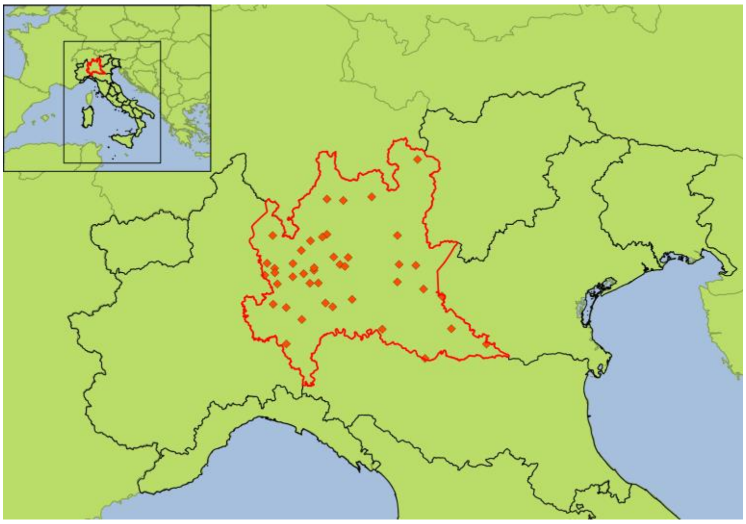

Figure 1. CAMx computational domain over Italy (small panel) and Lombardy Region (main panel, red borders). Lombardy air quality monitoring stations (red squares).

Anthropogenic emissions were represented starting from 2017 EMEP (European Monitoring and Evaluation Program) emission inventory (Mareckova et al., 2019). The inventory was then processed using the High-Elective Resolution Modelling Emission System version 3 – Global_Regional (HERMESv3_GR) model (Guevara et al., 2019). This model allowed the spatialization of the EMEP emissions on CAMx domain and grid, the temporal disaggregation from annual to hourly emission values and the speciation of EMEP pollutants to CAMx chemical mechanism (CB05e51) species. Biogenic emission and sea salt were estimated using the Model of Emissions of Gases and Aerosols from Nature (MEGAN v2.03) (Guenther, et al., 2006) and SEASALT model (Ramboll Environ, 2015). Boundary and initial conditions were obtained from the CHIMERE model with the INERIS' Prev'Air service (Institut National de l'EnviRonnement Industriel et des RisqueS (INERIS), 2021).

Scenarios set-up

The variation of NO_2, PM_{10} and $PM_{2.5}$ atmospheric concentration during the lockdown was evaluated by comparing two simulations representing the actual road traffic emissions and concentration with a BAU one (based on EMEP inventory emissions). We refer to the first two simulations as "lockdown scenarios". The analysed period extends from the 24^{th} of February to the end of April.

Both lockdown scenarios namely LOCK_1 and LOCK_2 were based on rescaled emission fields for the road transport sector. Weekly average coefficients were applied to BAU emissions, the main difference is the way the emission coefficients were obtained.

- LOCK_1 scenario was based on emission fields that are calculated by using the emission reduction coefficients from literature. They were computed specifically for the assessment of the effect of spring lockdown on Lombardy emission by ARPA Lombardia, which is the local environmental protection agency (Marongiu, et al., 2020). The ARPA dataset is freely available and all the emission source are included. For the purpose of this study only the road transport emission coefficients were applied.
- LOCK_2 scenario relied on mobility trend data, based on mobile phone data as a proxy for emission reduction. The dataset used is based on the "COVID-19 mobility trends" published by Apple (https://covid19.apple.com/mobility). Weekly scenarios coefficients for LOCK_2 were computed selecting the driving category for Lombardy considering the week starting on January 13^{th} as a reference and are applied to all EMEP pollutants.

Outside Lombardy, emissions were calculated using LOCK_2 methodology for both scenarios, using region-specific coefficients for Italy and country-specific information for neighbouring countries. LOCK_1, being based on a literature dataset, was used as a benchmark to evaluate the performance of LOCK_2.

RESULTS AND DISCUSSION

Concentration reduction and model validation

For the national lockdown period (March 9th-end of April) we found an average concentration drop of 37.2% for NO2, 15.3% for PM10, and 17% for PM2.5 between LOCK_1 and BAU. The comparison of modelled data with concentration measured in urban and suburban background sites by the regional air quality network (**Figure 2**) shows good performance for PM_{10} and $PM_{2.5}$, while for NO_2 the modelled concentration underestimate the measured concentration, especially during the pre-pandemic and first two weeks of the pandemic study period.

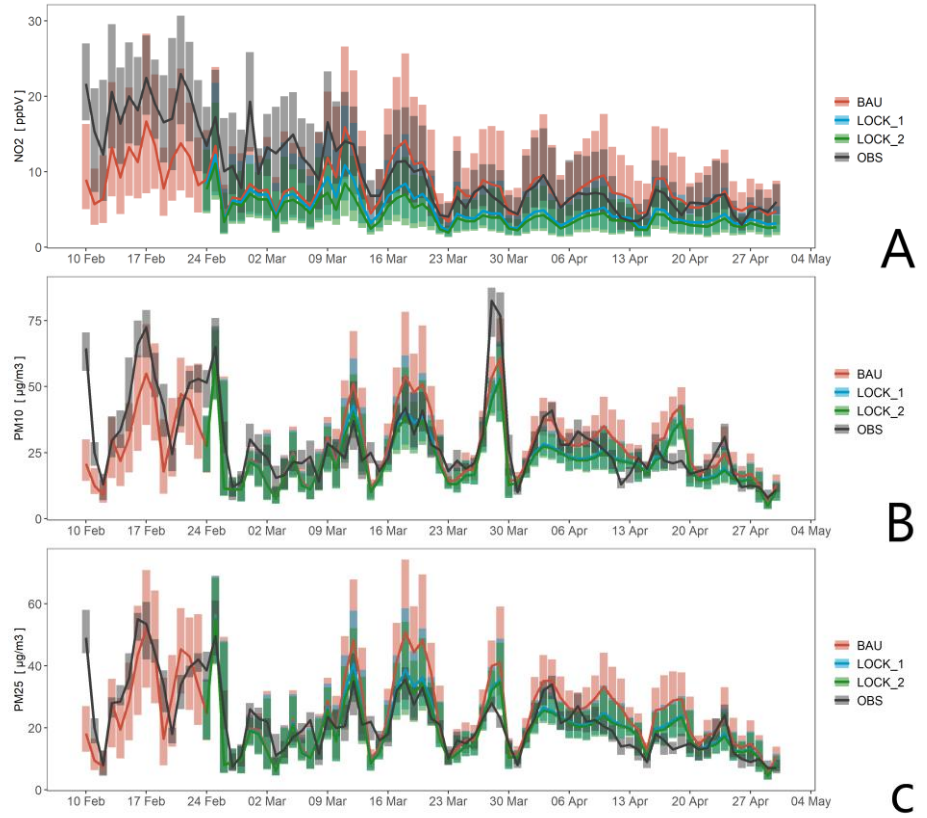

Figure 2. Comparison of observed (OBS) and modelled (BAU, LOCK_1, LOCK_2) concentration for Urban and Suburban Background monitoring stations for NO_2 (42 sites) (A), PM_{10} (34 sites) (B) and $PM_{2.5}$ (15 sites) (C). Bars show the interquartile range (25th-75th) and lines the median values.

In **Table 1** the statistical scores of daily means are presented in terms of normalised mean bias (NMB), root mean square error (RMSE) and Pearson's correlation (R) for urban and suburban monitoring stations. BAU simulation is included as a reference to better highlight the variations of model performance in scenario mode. For NO_2 an improvement in RMSE and R was found for both scenarios compared to the BAU simulation, but the NMB increased in absolute terms and indicated the tendency to underestimate the actual concentration levels.. Similar results were found for PM_{10}, but with a smaller difference among NMB absolute values. For $PM_{2.5}$ all the performance indicators improved when considering traffic reduction in scenarios.

Table 1. Statistical scores of daily means computed for Urban and Suburban Background air quality monitoring stations. RMSE are in ppb for NO_2 and in $\mu g m^{-3}$ for PM_{10} and $PM_{2.5}$

	NO2			PM10			PM2.5		
	NMB	RMSE	R	NMB	RMSE	R	NMB	RMSE	R
BAU	0.071	6.462	0.578	0.065	12.196	0.693	0.301	12.615	0.620
LOCK_1	-0.281	5.296	0.675	-0.082	11.139	0.715	0.111	9.522	0.640
LOCK_2	-0.390	5.713	0.676	-0.110	11.054	0.725	0.075	9.010	0.646

Lockdown scenario comparison

The estimated concentration reductions for NO_2 are higher in the LOCK_2 scenario, especially in the first two weeks of the study period and of the lockdown. For both $PM_{2.5}$ and PM_{10}, the discrepancies between the two scenarios were negligible. In **Figure 3** the average relative and absolute difference between LOCK_2 and LOCK_1 pollutant concentration for the period 9th March 2020 to 30th April 2020 are presented for NO_2 and PM_{10}. $PM_{2.5}$ differences are not show in **Figure 3** because of the similarity with PM_{10} results. For $PM_{2.5}$ the absolute difference scale and pattern are the same of PM_{10}, while for the relative difference the pattern is the same but the scale goes up to 5.4%.

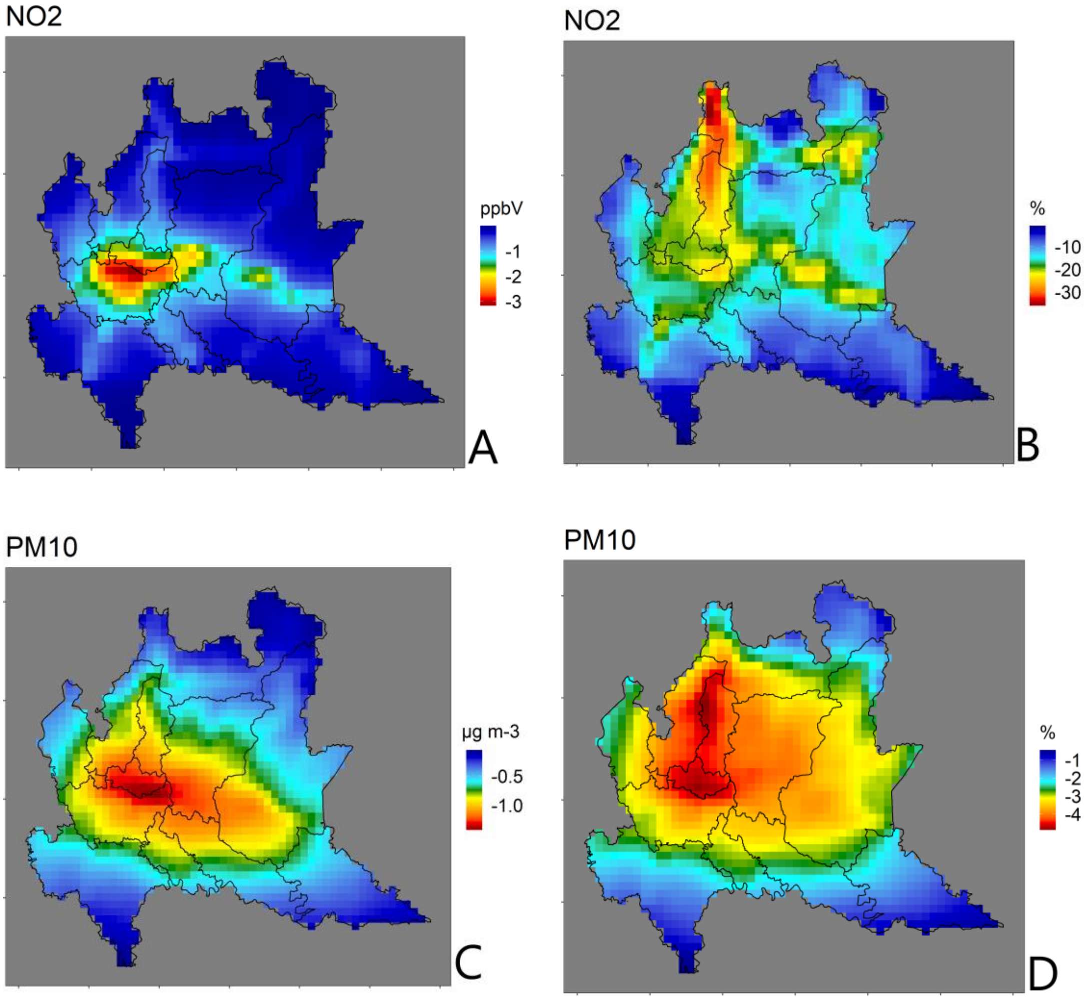

Figure 3. Absolute concentration difference between scenarios for NO_2 and PM_{10} (A, C) and relative concentration difference between scenarios for NO_2 and PM_{10} (B, D)

The difference in the emission coefficients had a greater effect on NO_2 concentration due to the high contribution of the road transport sector to the NOx total emission. For particulate matter, the importance of secondary aerosol and the smaller contribution of the road transport sector to the primary aerosol emission and total particulate matter concentration (Pepe et al., 2019) leads to both lower relative difference between the two lockdown scenarios, as well as between them and BAU. Despite registering high relative differences between the two scenarios for NO_2, the absolute concentration differences were generally lower than 1 ppbV in most of the domain. For PM_{10} and $PM_{2.5}$ the differences between scenarios are low in both absolute (a few µg m^{-3}) and relative terms (maximum 5%). Analysing performance indicator presented in **Table 1**, no significant differences were visible in RMSE and R, while for NMB differences are relevant only for NO_2.

The coherence between LOCK_1 and LOCK_2 scenarios showed that mobile phone data can be used without intensive processing in assessing mobility scenario if specific datasets are not available. The main drawback of these kind of data is the lack of detail on vehicle type. Using a single coefficient for the entire road transport sector can lead to a misrepresentation of the active vehicle fleet and therefore of the actual emissions, e.g. during the lockdown private sector mobility decreased more than the commercial one, but this split was not represented in the LOCK_2 dataset, while it is accounted for in the LOCK_1 dataset.

CONCLUSIONS

We developed two scenarios to simulate the effects of the COVID-19 lockdown on NO_2, PM_{10} and $PM_{2.5}$ ambient concentrations in Lombardy. The validation of modelled data for urban environment showed good performance for particulate matter, while for NO_2 the modelled concentration underestimates the observations. We were also able to perform a mobility scenario simulation using mobile phone data, with minimal pre-processing on our part, to assess emission reductions from traffic. Considering the good performance of both approaches and the few differences between modelled scenarios we believe that mobile phone data are an effective proxy for mobility studies if specific datasets are missing.

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