HARMO21

PROCEEDINGS

27-30 September, Aveiro, Portugal
University of Aveiro

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HARMO 21

21st International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
27-30 September 2022 | Aveiro, Portugal

PROCEEDINGS

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AVEIRO, 2022

History of the Harmonisation Workshop/Conference:
1st Harmo workshop, Risø National Laboratory, Denmark, 1992
2nd Harmo workshop, Manno, Switzerland1993
3rd Harmo workshop, Mol, Belgium, 1994
4th Harmo workshop, Oostende, Belgium, 1996
5th Harmo conference, Rodos, Greece, 1998
6th Harmo conference, Rouen, France, 1999
7th Harmo conference, Belgirate, Italy, 2001
8th Harmo conference, Sofia, Bulgaria, 2002
9th Harmo conference, Garmisch-Partenkirchen, Germany, 2004
10th Harmo conference, Crete, Greece, 2005
11th Harmo conference, Cambridge, UK, 2007
12th Harmo conference, Cavtat, Croatia, 2008
13th Harmo conference, Paris, France, 2010
14th Harmo conference, Kos, Greece, 2011
15th Harmo conference, Madrid, Spain, 2013
16th Harmo conference, Varna, Bulgaria, 2014
17th Harmo conference, Budapest, Hundary, 2016
18th Harmo conference, Bologna, Italia, 2017
19th Harmo conference, Bruges, Belgium, 2019
20th Harmo conference, Tartu, Estonia, 2021

The scientific focus of Harmo 21 is on the following topics:
• Model evaluation and quality assurance – model validation, model intercomparisons, model uncertainties and model sensitivities
• Environmental impact assessment: Air pollution management and decision support systems
• Use of modelling in support of EU air quality directives, including FAIRMODE
• Parametrization of physical processes in mesoscale meteorology relevant for air quality modelling
• Urban scale and street canyon modelling: Meteorology and air quality
• Use of modelling in health and exposure assessments • Inverse dispersion modelling and source identification
• Modelling air dispersion and exposure to accidental releases
• Mathematical problems in air quality modelling
• Highlights of past work. Session devoted to reviews and to prominent scientists and 'golden papers' of the past, which have still relevance and should not be forgotten
• Nature-based Solutions

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TIME SERIES ANALYSIS OF METEOROLOGICAL PARAMETERS AND AIR POLLUTION CONCENTRATIONS IN EMILIA-ROMAGNA, ITALY, DURING COVID-19 INFECTION

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Abstract: During the pandemic, Italy experienced several phases of lockdown with different types of restrictions. Starting on February 23rd 2020, 11 municipalities in northern Italy suspended activities in schools, universities, museums, cultural venues, and all public initiatives. The ordinance announcing the national emergency was released on March 11th, stabilising the first lockdown period for the whole of Italy, which lasted until the second half of May. After a phase of cushioned restrictions during the summer, the so-called 'Second Wave' began forcing a new ordinance on October 13th with more stringent restrictions as the number of infections increased. On November 3rd, the "colour system" was introduced with three risk bands - red, orange and yellow - assigned weekly to the regions based on monitoring indicators. The main objective of the present study is to assess the impact of the meteorological and air quality conditions on COVID-19 cases in the region of Emilia-Romagna in Italy during the lockdown periods. Several pollutant time series from the Copernicus Atmosphere Monitoring Service were joined with meteorological data from the daily gridded land-only observational dataset over Europe and then compared with the total number of infections, hospitalisations and deaths. Data provided by the two monitoring systems were processed through an algorithm and organised by provinces and municipalities in Emilia-Romagna, Italy. The explorative analysis, conducted using both time series and seasonally adjusted time series, shows that pollutants most affected by lockdown phases are CO, NO_2, PM_{10}, $PM_{2.5}$ and SO_2. The findings in this study may help further studies better understand the variations 2020 and 2021 and the correlation with COVID-19 variables.

Key words: *COVID-19; Environmental Pollution; Meteorological Data; Correlation; Time Series.*

INTRODUCTION

Air pollution is one of the environmental causes of premature death in Europe. A study from the WHO (2013) suggests that the disease burden attributable to the air pollution exposition is substantial. Several researches have been conducted to assess the impact of air quality on the COVID-19 contamination. In Italy, Lolli *et al.* (2020) quantitatively assess how the meteorological and air quality parameters are correlated to the COVID-19 transmission in Milan, Florence and in Trento that are located in Italian regions, respectively Lombardy, Tuscany and Trentino-South Tyrol. Through the usage of Spearman and Kendall rank correlation tests, the authors put in evidence that temperature, dew point temperature, absolute humidity, water vapor are negatively correlated with the virus transmission. On the other hand, wind speed and atmospheric mean sea-level pressure show a certain degree of correlation, while $PM_{2.5}$ concentration positively correlates with COVID-19 transmission. These results require further investigation considering other Italian cities and regions. Another Italian territory-based study (Accarino *et al.* 2021) analyzes atmospheric pollutants concentrations (i.e., PM_{10}, $PM_{2.5}$, NO_2) and spatio-temporal distribution of COVID-19 positive cases and deaths. It evidences any potential short-term correlation between these two phenomena via Spearman's correlation index. Both studies use Spearman correlation coefficient to assess non-linear, monotonic correlations between the number of days exceeding regulatory limits for the selected pollutants and COVID-19-related parameters at territorial levels. PM_{10} and $PM_{2.5}$ show higher non-linear correlation than NO_2 with incidence, mortality and lethality rates.

This present study aims to explore the relationship between the COVID-19's spread and the meteorological and air quality conditions in the nine Emilia-Romagna (Italy) provinces (Figure 1): Piacenza, Reggio Emilia, Parma, Modena, Bologna, Ferrara, Forlì Cesena, Ravenna and Rimini. Emilia-Romagna is one of the regions that has been significantly affected by COVID-19. Starting from Piacenza province in the western part of the region, the virus spread to the central provinces in the direction of Bologna and Modena. With respect to the aforementioned studies, we have considered a larger number of air quality variables and investigated the correlations between seasonally adjusted air quality parameters and COVID-19.

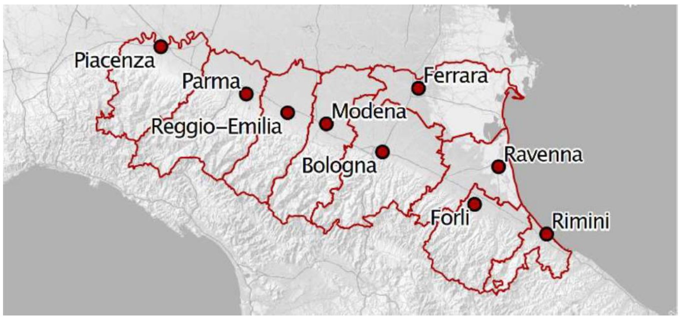

Figure 1. Distribution of the Emilia-Romagna provinces in northern Italy.

MATERIALS AND METHODS

For this study, three main steps have been pursued. Firstly, we have identified variables of interest in four categories: meteorological, COVID-19, air quality and geographical & socio-economical (Figure 2). The meteorological and air quality variables have been extracted at the municipal level of Italy and later transformed into the nine provinces of Emilia-Romagna. Then, the explorative analysis and the correlation analysis have been performed.

	Meteorological	Air quality	Covid-19	Geographical and Socio-Economical
Source	E-OBS	CAMS	CovidStat	ISTAT
Area	Italy	Italy	Emilia-Romagna	Emilia-Romagna
Period	01/01/2017 - 31/12/2020	25/12/2017 - 31/07/2021	05/03/2020 - 20/01/2022	2017-2021
Frequency	Daily	Hourly	Daily	Yearly
Variables	TG, RR, PP, QQ, HU	CO, SO_2, NMVOCs, NO, NO_2, NH_3, O_3, PANs, $PM_{2.5}$, PM_{10}	Positive Cases, Hospitalization, Deaths, Intense Care Unit cases	Population, Ages, Hospitals, Tourism, Province Areas

Figure 2. Datasets characteristics by typology.

Meteorological data are from the European Observations (E-OBS) ensemble datasets (*https://climate.copernicus.eu/*), which include daily climate measurements interpolated to provide gridded data with a spatial resolution of 10 × 10 km, approximately. The available parameters are: daily mean temperature (TG), daily minimum temperature (TN), daily maximum temperature (TX), daily precipitation sum (RR), daily mean sea level pressure (PP), daily mean relative humidity (HU) and global radiation (QQ). To reduce them to the municipality level, all grid points within the municipality area plus those up to 10 km from the border have been averaged. The four most neighbouring grid points have been employed whenever the municipality's area has been less than 100 km² (Figure 3). Consequently, we guarantee that all averages used have at least four values in their calculation, avoiding errors associated with the grid points' choice. Finally, to reduce to the provincial level, weighted averages have been assembled based on the area of each municipality within the province. Air Quality data are from the Copernicus Atmosphere Monitoring Service (CAMS, *https://atmosphere.copernicus.eu/*), implemented by the European Centre for Medium-Range meteorological Forecasts on behalf of the European Commission. We have applied the same procedure described for the meteorological data. However, as the CAMS data have an hourly frequency, it has been necessary to reduce them to daily. The highest daily concentrations have been collected at each grid point, following the analysis periods of each pollutant to proceed with the spatial averages. For species without Air Quality Standard, the highest hourly concentration has been considered. In the end, the concentrations were available daily and at the provincial level.

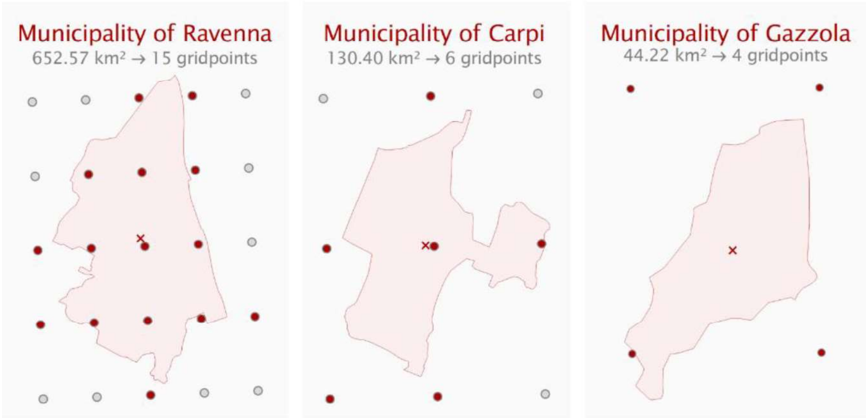

Figure 3. Examples of grid point selection for E-OBS and CAMS data extraction to municipalities with different dimensions. In both datasets the spatial resolution is approximately 10 km and marks the distance between grid points, where those highlighted in red are considered for data extraction.

COVID-19 variables have been extracted from COVIDStat (https://covid19.infn.it/) that reports daily information at provincial level, computed using a 7-days centered moving average. Geographical and socio-economical information are from the Italian Institute for Statistic (ISTAT, https://www.istat.it/it/archivio/156224). Particularly, the municipalities areas (km^2) and the provincial groups have been used to reduce meteorological and air quality data to province level.

The relationship between meteorological and air quality variables versus COVID-19 related variables is analysed using different techniques, both explorative through smoothing techniques, i.e., 7-days centered moving average and seasonal adjustment with the additive decomposition of original datasets, and statistical through Spearman's correlation indexes.

RESULTS

One of the first steps of our explorative analysis consisted in understanding how meteorological and air quality variables influence each other. Correlograms (https://r-graph-gallery.com/correlogram.html) computed for each province show a very similar behavior.

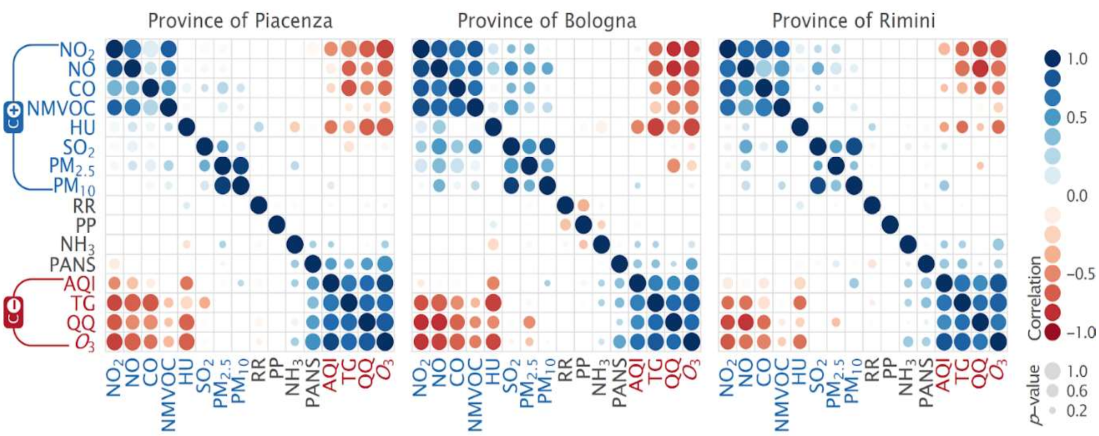

Figure 4. Correlation heatmap between and meteorological and air quality parameters for provinces of Piacenza, Bologna, and Rimini.

In Figure 4, plots relating to the provinces of Piacenza, Bologna and Rimini illustrate different areas of Emilia-Romagna, from northwest, center and southeast, respectively. Variables are sorted according to the first principal component order. According to Figure 4, it is possible to define two groups of parameters, which tend to be negatively correlated to each other: (1) C+ that comprises NO_2, CO, NO, NMVOC, Air Relative Humidity, SO_2, $PM_{2.5}$ and PM_{10}; and (2) C- that comprises AQI, TG, QQ, and O_3. The C+ group tends to be higher in winter and autumn, and lower in the hotter periods. On the other hand, while the C- group presents parameters with opposite correlation behaviour (Figure 4). Precipitations, Sea Level Pressure, PANs, and NH_3 parameters are not considered in the analysis because they do not fit in any group since they have no strong correlations with any other parameter.

Figure 5 shows time series of meteorological and air quality parameters belonging to the C- group (i.e., O_3 and TG) and the C+ group (i.e. NO_2, SO_2 and HU). For Nitrogen Dioxide, the first lockdown period presents smoothly lower concentrations than the previous years, while the second lockdown points increased variations in concentrations that started one month before. For Sulphur Dioxide, the first lockdown highlighted higher concentrations in comparison with the same period in years preceding 2020. Timeseries of C- group parameters show entirely different behaviours. For example, O_3 concentrations rise as temperature increases, while they decrease with high precipitation, which helps clean air from particles. During both lockdown periods, O_3 concentrations were slightly above the previous year's levels, showing the impact of reducing vehicle fleet emissions of NO_2. This shows the role of seasonal cycles over air quality parameters and the importance of seasonally adjusting them. Finally, as expected, the meteorological parameters TG and HU presented no significant variations along the analysed period, remarking a small inter-annual variation that helps to fairly compare the air quality parameters.

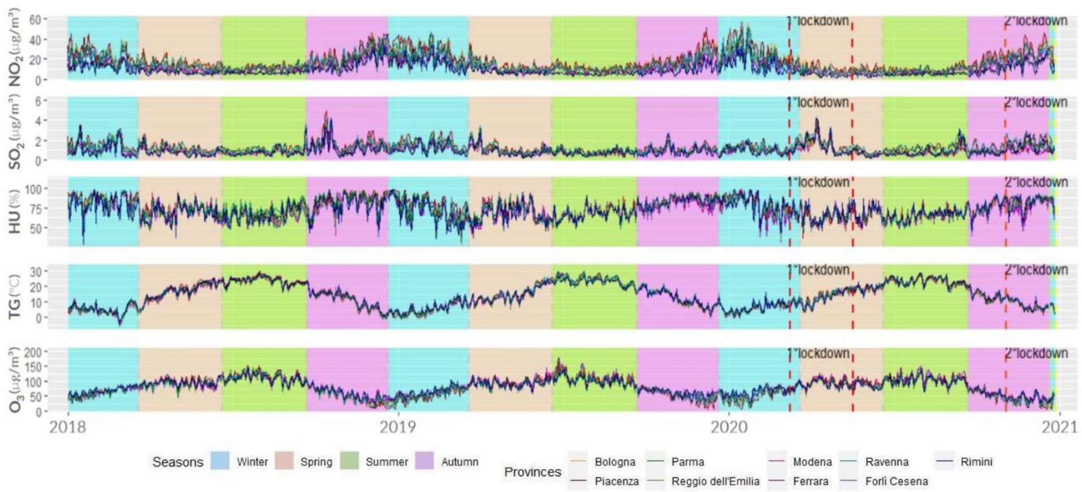

Figure 5. Time series of the analysed parameters from 01/01/2018 to 31/12/2020. Dotted lines remark the two lockdown periods in Emilia-Romagna.

After the explorative analysis, in which all the years covered by the datasets available for analysis have been considered, for the correlation analysis we have just considered the period from 05/03/2020, i.e., the date from which we have available information on the number of COVID-19 positives, deaths, hospitalizations and intensive care units, to the end of 2020. Year 2020 has been selected both because it was characterised by lockdown phases common to the whole of Italy and because at that time the vaccination campaign had not yet started, so the incidence number is not affected by the percentage of vaccinated persons.

In order to obtain seasonally adjusted air quality parameters, firstly original time series covering the complete period available have been split in their three main components (*https://www.rdocumentation.org/packages/stats/versions/3.6.2/topics/decompose*), i.e. seasonal component, trend component and reminder, through additive decomposition, then the seasonal component have been subtracted from the original data. Seasonally adjusted air quality parameters that show an interesting behaviour for the province of Bologna are shown in Figure 6, scaled with respect to their mean and standard deviation, to make them comparable on the same plot. Shaded areas represent lockdown phases in Emilia-Romagna: Period 1 (red) correspond to the first lockdown period for the whole Italy; Periods 2 and 3 represent part of the second lockdown when the colour system was introduced with three risk bands weekly assigned to each region based on monitoring indicators. In this period, Emilia-Romagna was classified initially as High-risk zone (orange) and then as moderate-risk zone (yellow). In Figure 6, the seasonal adjusted concentrations highlight the increase of fluctuations in the first phase but especially in the last two phases of the lockdown for variables belonging to Group C+ (i.e., SO_2, PM_{10}, CO and NO_2) that tends to be flatter between June and October 2020. Both behaviors show a similarity with COVID-19 parameters (dotted lines). On the other hand, after being seasonally adjusted, O_3 (pink) and PANs (dark blue) concentrations tend to be noisier, suggesting to be unaffected by seasonality and reinforcing the results presented in Figure 5.

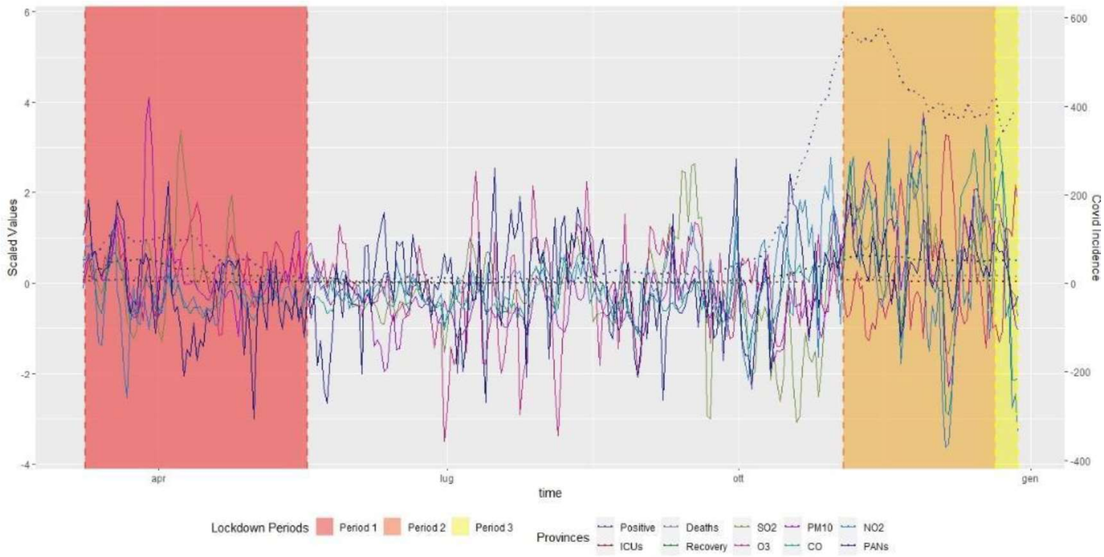

Figure 6. Scaled seasonally adjusted time series vs COVID-19 incidence with lockdown period marked in different colours in the province of Bologna from 05/03/2020 to 31/12/2020.

CONCLUSIONS

This study has explored the relationship between meteorological parameters and air quality parameters during the COVID-19 pandemic. Through time series analysis we have qualitatively shown the influence that lockdowns have had on certain air quality variables, such as SO_2, PM_{10}, CO, NO_2, NO, $PM_{2.5}$. Furthermore, the seasonal adjusted concentrations highlight a trend towards increased C+ group (i.e. SO_2, PM_{10}, CO and NO_2) fluctuations in the first phase but especially in the last two phases of the lockdown. The concentrations tend to be flatter between June and October 2020. Similar behaviours have been observed with the COVID-19 variables. Our findings show the need of considering seasonal adjusted parameters in the spread of COVID-19 pandemic. It may be useful to understand the role of seasonality during COVID-19 transmission in order to e.g., better formulate public health interventions.

ACKNOWLEDGEMENTS

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