Time series analysis of meteorological parameters and air pollution concentrations in Emilia-Romagna, Italy, during COVID-19 infection

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INTRODUCTION

This 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). The region was significantly affected by COVID-19 starting from Piacenza and latter moving to the central provinces in the direction of Bologna and Modena. We have considered a larger number of air quality variables and investigated the correlations between seasonally adjusted air quality parameters and COVID-19.

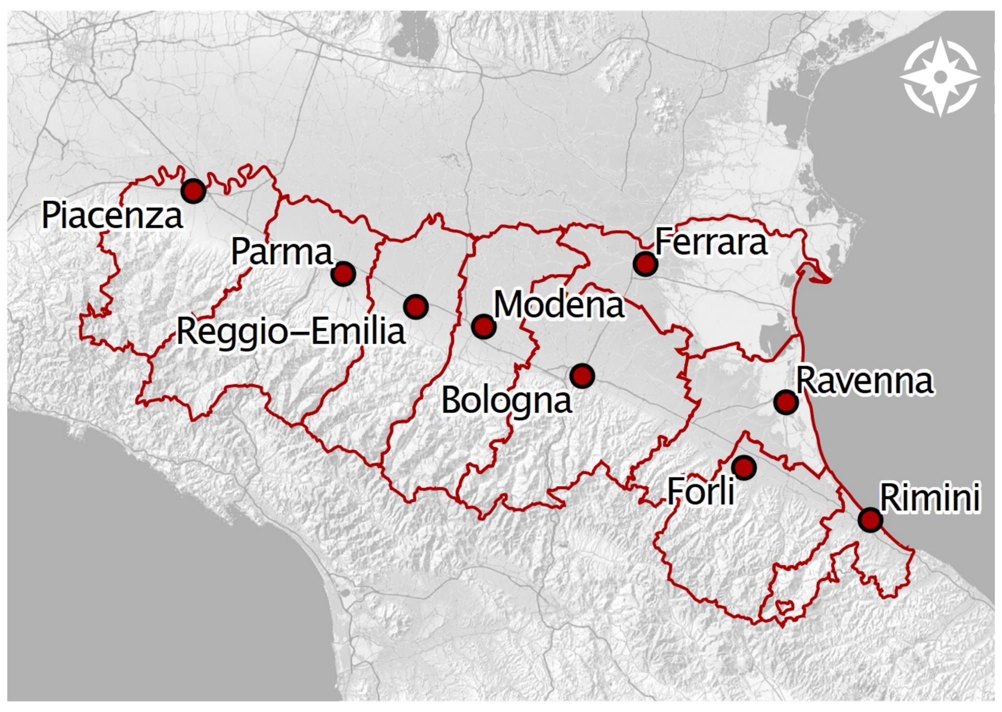

Figure 1
Distribution of the Emilia-Romagna provinces in northern Italy.

MATERIALS AND METHODS

The analysis is based on several variables divided into four categories (Table 1).

	Meteorological	Air quality	Covid-19	Geo-Socio-Economic
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, ICU, Deaths	Population, Ages, Hospitals, Turism, Province Areas

Table 1 *Datasets characteristics by typology.*

Meteorological data include daily climate measurements interpolated to provide gridded data with a spatial resolution of 10×10 km, approximately. 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 2). 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. We have applied to the air quality data the same procedure described for the meteorological data. In the end, the concentrations were available daily and at the provincial level.

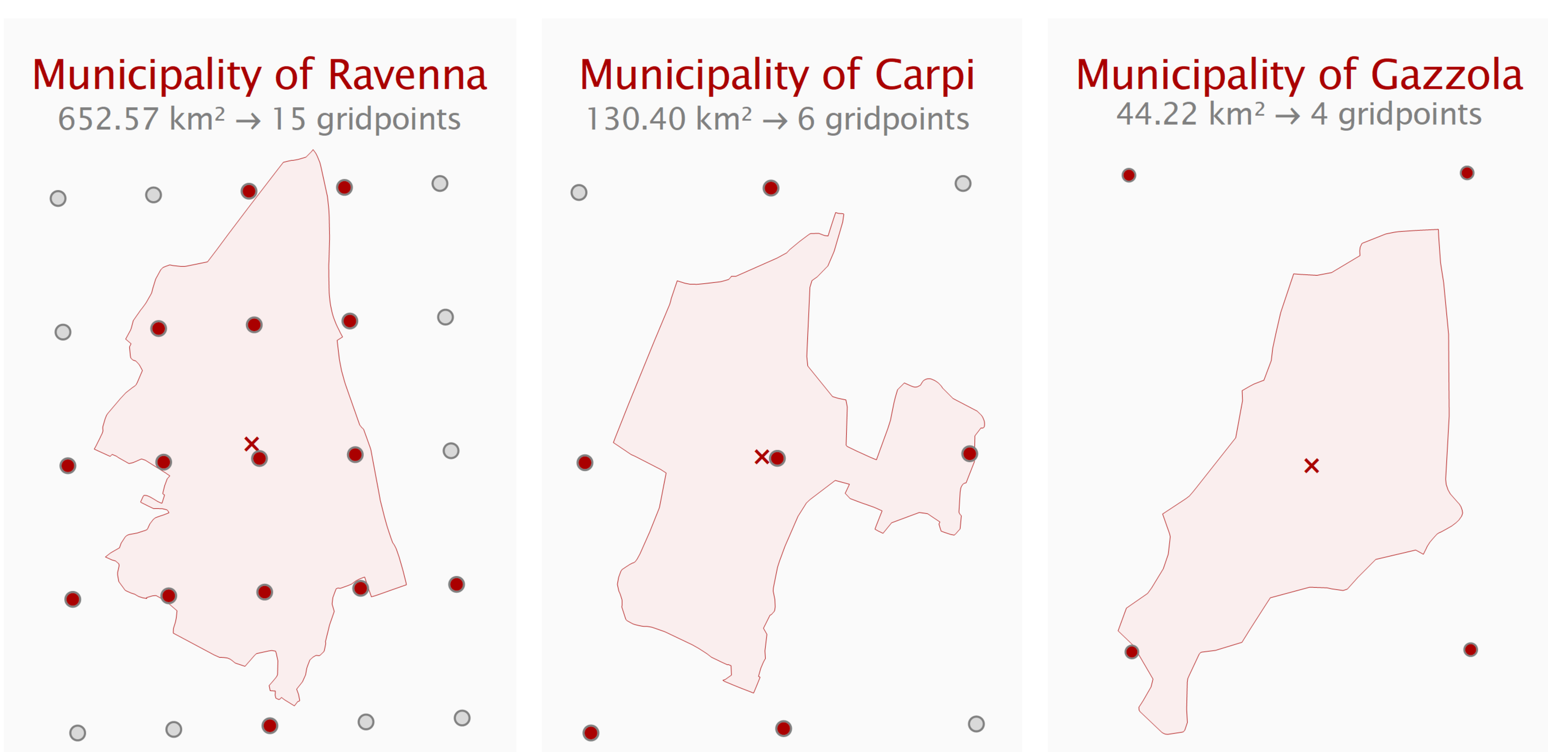

Figure 2 *Examples of grid point selection for E-OBS and CAMS data extraction to municipalities with different dimensions. In both datasets the spatial resolution is approximately 10 km and marks the distance between grid points, where those highlighted in red are considered for data extraction.*

RESULTS AND DISCUSSIONS

Figure 3 illustrates different areas of Emilia-Romagna, from northwest, center and southeast. Variables are sorted according to the first principal component order. We have defined two groups of parameters, which tend to be negatively correlated to each other: (1) **C+**, which comprises NO_2, CO, NO, NMVOC, air relative humidity, SO_2, $PM_{2.5}$ and PM_{10}, tends to be higher in winter and autumn, and lower in the hotter periods; and (2) **C–**, which comprises AQI, TG, QQ, and O_3, presents parameters with opposite correlation behaviour.

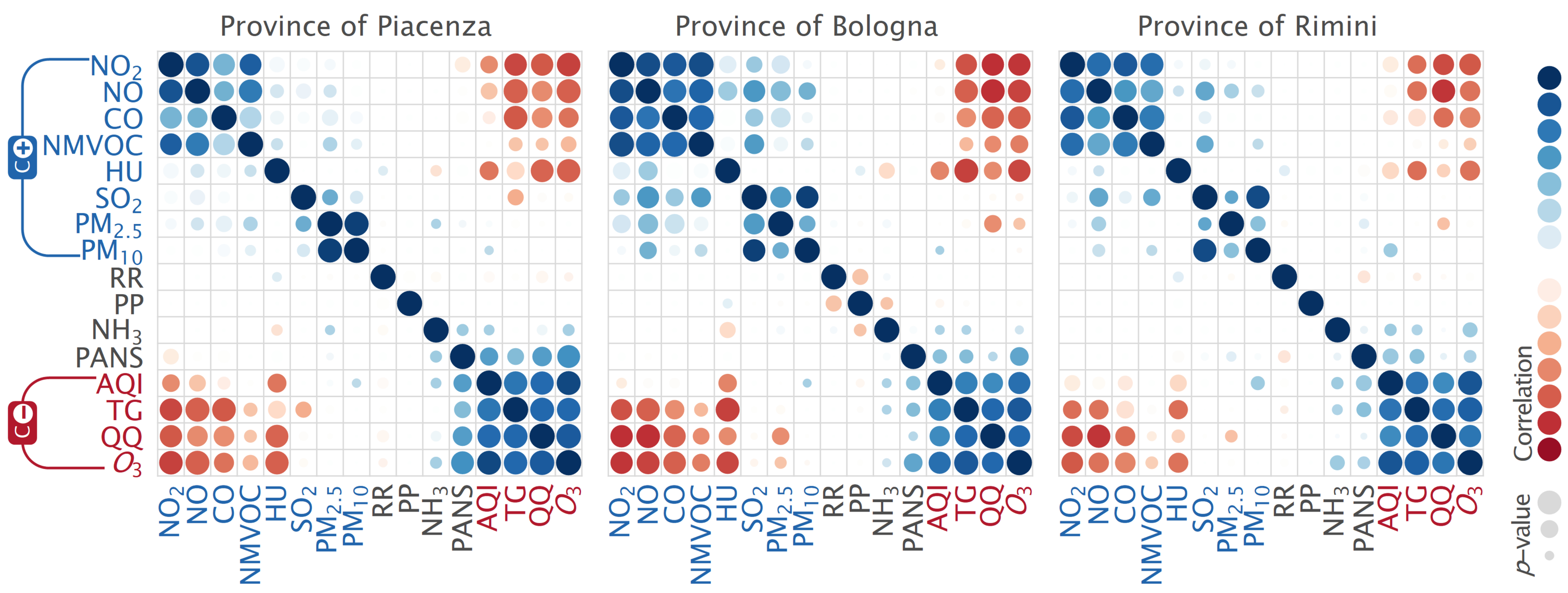

Figure 3 *Correlation heatmap between meteorological and air quality parameters for provinces of Piacenza, Bologna, and Rimini.*

Figure 4 shows time series of meteorological and air quality parameters belonging to the **C–** group (O_3 and TG) and the **C+** group (NO_2 and SO_2). For NO_2, 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 SO_2, 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 TG and all meteorological parameters presented no significant variations along the analysed period, remarking a small inter-annual variation that helps to fairly compare the air quality parameters.

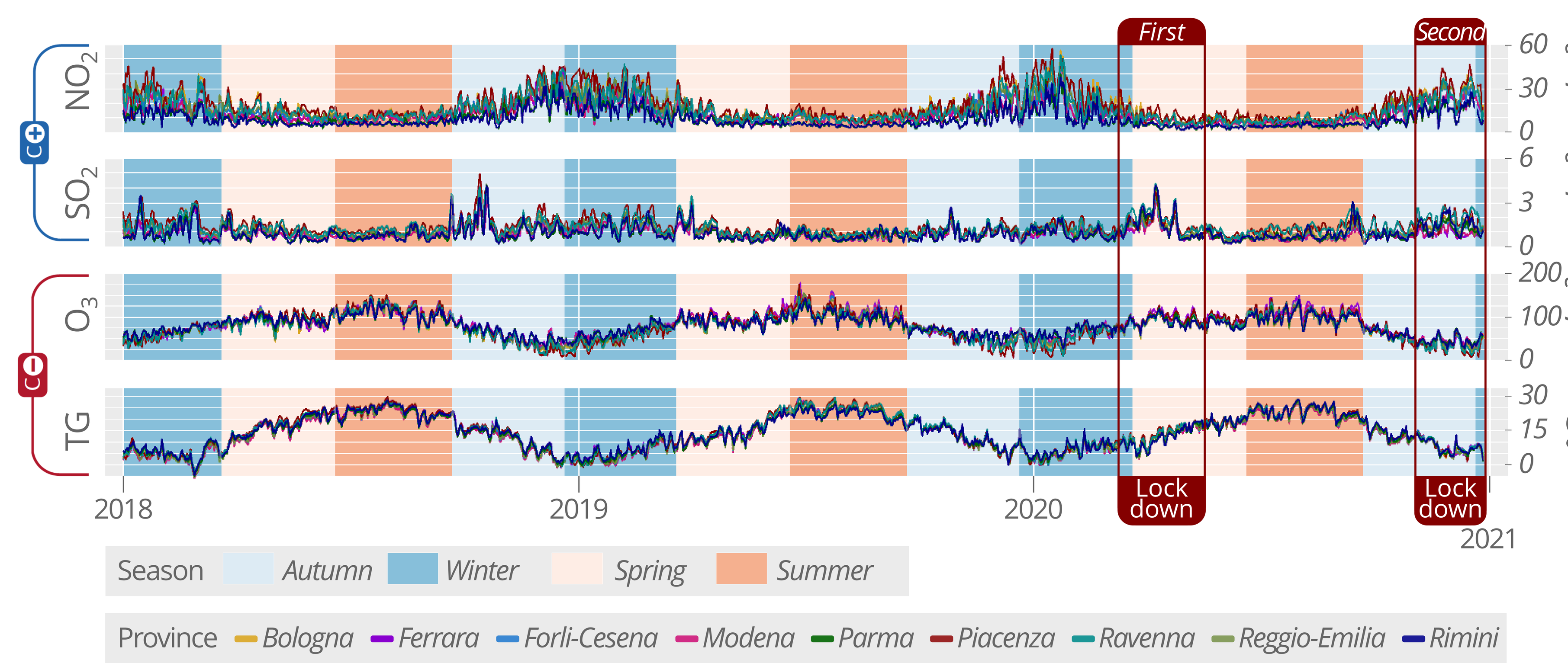

Figure 4 *Time series of the analysed parameters from 01/01/2018 to 31/12/2020. Dotted lines remark the two lockdown periods in Emilia-Romagna.*

In Figure 5, 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 behaviours show a similarity with COVID-19 parameters. On the other hand, after being seasonally adjusted, O_3 and PANs concentrations tend to be noisier, suggesting to be unaffected by seasonality and reinforcing the results presented in Figure 4.

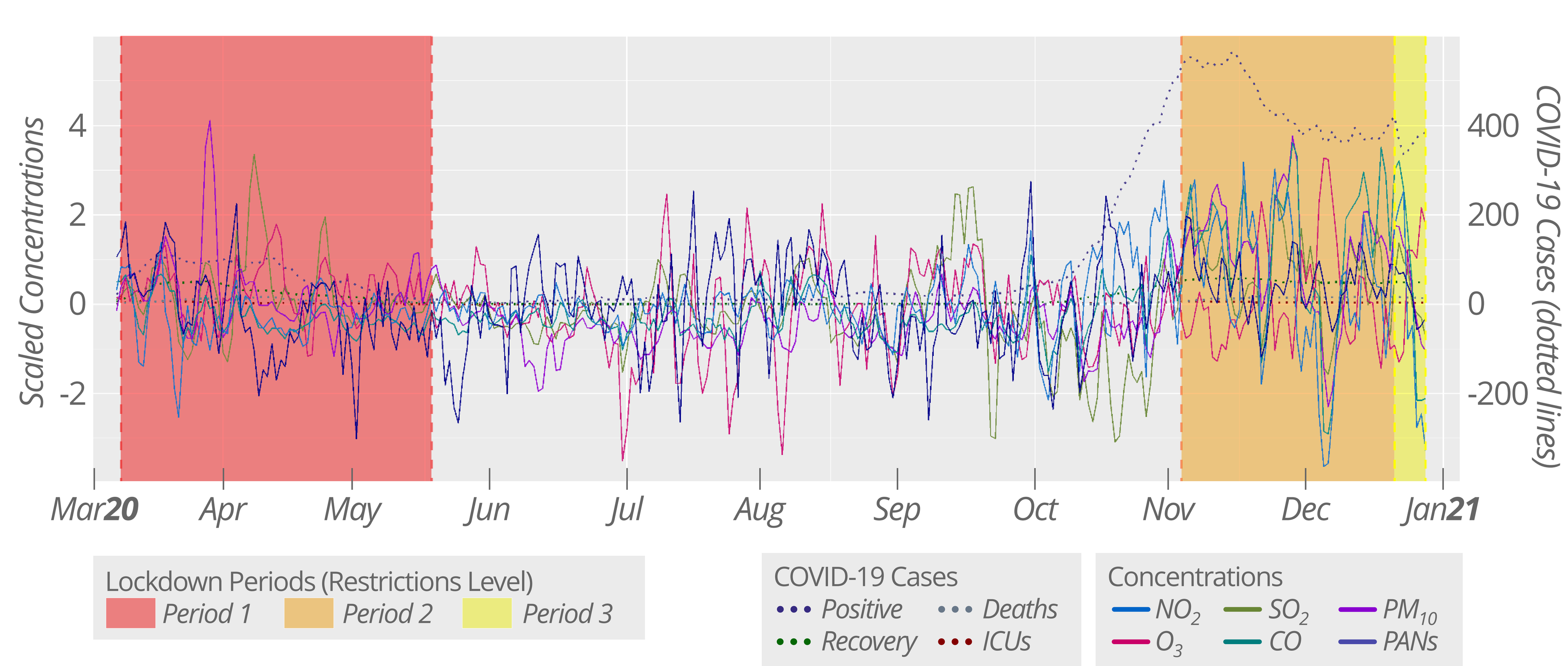

Figure 5 *Scaled seasonally adjusted time series vs COVID-19 incidence with lockdown period marked in different colours in the province of Bologna from 05/03/2020 to 31/12/2020.*

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