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A Regional Geography Approach to Understanding the Environmental Changes as a Consequence of the COVID-19 Lockdown in Highly Populated Spanish Cities

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Abstract: Spain has been highly impacted by the COVID-19 pandemic, which is reflected at different scales. From an economic point of view, lockdowns and the reduction of activities have damaged the country (e.g., complete lockdown from March 13 to June 21, 2020). However, it is not clear if the associated environmental impacts could be observed in 2020. Currently, studies on the effects of the lockdown (e.g., decrease in economic activities, transport and social communication) on specific parameters related to climate change, such as air temperature or air pollution, due to a drastic decrease in human activities are rare. They are focused on specific cities and short periods of time. Therefore, the main goal of our research will be to assess the records of air temperature and air quality during the whole of 2020 compared to references from previous years (30 years for air temperature and 10 for air quality). We paid attention to the possible effects of the reduction of activities (e.g., tourism and transport) in March, April and May and the different restrictions of each lockdown in Spain. To achieve this goal, five urban climate stations with long-term time series within the most populated cities of Spain were analyzed (Barcelona, Madrid, Málaga, Sevilla and Valencia). We conclude that it is possible to affirm that the impacts of the COVID-19 pandemic on the atmospheric conditions in 2020 are not clear and not strictly focused on the lockdown or reduction of activities in these urban areas. No evidence of a reduction in the annual air temperature was found, and only a minimum reduction of rates of pollutants was registered in the highly populated cities of Spain. Therefore, it is worth confirming that these changes could be affected by other factors, but on a global scale and not directly due to the COVID-19 pandemic. Considering recent studies on the relationships between air pollutants, temperature and the spreadability of COVID-19, green policies must be further imposed in urban cities, since temperatures do not stop increasing year by year.

Keywords: COVID-19; regional geography; epidemiology; data mining; climate variations

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1. Introduction

The year 2020 was the first full year affected by a reduction in human activities as a consequence of the COVID-19 pandemic. The economic crisis triggered by the restrictions of activities and travel involves societal, environmental and health issues. This is affecting all the countries in the world [1,2]. This crisis also offers unprecedented insights into how climate change [3] and the air pollution crises [4] may be managed. Scholars, policymakers and stakeholders do not agree if the reduction of transport, tourism, social communication and economical activities does or does not affect the air temperature on a regional or global scale [5,6]. Hepburn et al. [7] affirmed that imminent fiscal recovery packages could entrench or partly displace the fossil fuel-intensive economic system, and the financial support for lower- and middle-income countries and rural areas could be of special relevance. Therefore, now, it is necessary to focus on cities and peri-urban areas.

Newman [8] announced that one of the most affected territorial realities of COVID-19 is the city. This author affirmed that urban scientists could observe new features such as relocalized city centers, tailored innovations in each urban fabric, less automobile use and an increase in symbiotic partnerships for funding. Therefore, cities and peri-urban areas must be prepared, and policymakers must develop strategic and sustainable plans to minimize the negative impacts and allow economical readaptations [9]. Mende and Misra [10] warned that in the future, climate change and an increase in air temperature could even elevate the possibilities of registering more pandemics. However, this issue is controversial, and there is still no consensus on other types of SARS viruses [11]. Yao et al. [12] did not register a clear association between COVID-19 transmission and temperature or UV radiation after assessing Chinese cities. On the other hand, in New York, Farhan Bashir [13] concluded that mean and minimum temperatures and air quality showed a significant correlation with the COVID-19 epidemic, but no evidence of a reduction in infections if the weather became warmer. Sicard et al. [14] observed an increase in ozone by 24% in Nice, 14% in Rome, 27% in Turin, 2.4% in Valencia and 36% in Wuhan during the lockdown in 2020. In Italy, recent investigations highlighted that long-term air quality data was correlated with COVID-19, and specific regional trends with infections could be noted [15–17]. However, in China, other scholars did not find evidence of clear correlations between COVID-19 decline and weather conditions in 122 Chinese cities [18]. Gutiérrez-Hernándeza and García [19] remarked that the evidence on climate influence was not robust enough to be considered in public health policies and discussed that the correlative bioclimatic model of SARS-CoV-2 may lead to spurious conclusions. Therefore, whether COVID-19 will or will not affect climate change and air quality is an unresolved question at the moment [20,21]. Especially for the cities mentioned above, this topic is key, and there is a necessity to guide research in this direction to minimize global impacts on global warming and pollution.

Spain is one of the countries most affected by the COVID-19 crisis, suffering from different levels of lockdowns and reductions of activities, including (1) a complete lockdown from March 13 to June 21; (2) a severe lockdown from March 15 to May 10; and (3) flexible time from June 21(the new normality). It was dramatically affected in March 2020 after the spread of the SARS-CoV-2 virus in the north of Italy. Demographically, the Spanish population is concentrated in urban areas, like other Mediterranean countries, abandoning the rural ones, and the population has also aged [22–24]. Some estimations made by Spanish institutions (Fundación General CSIC) consider that in Spain, in the year 2050, people over 65 will represent more than 30% of the total population. Octogenarians will reach over four million (http://www.fgcsic.es/lychnos/es_es/articulos/envejecimiento_poblacion) (accessed on 18 March 2021). Both factors favor the spread of COVID. The first approaches are also contradictory, relating to the evidence of a relationship between COVID-19 cases and air temperature [25,26]. Páez et al. [27] argued that a higher incidence rate was related to an increase in GDP per capita and the presence of mass transit systems. On the other hand, they also estimated that the population density and percentage of older adults could play a negative role in the incidence of COVID-19. However, studies on the effects of the lockdown (e.g., decrease in economic activities, transport and social communication) on specific parameters related to climate change, such as air temperature or air pollution, due to a drastic reduction of human activities are scarce. They are focused on specific cities [28] and short periods of time [29,30], which are also vital to understand the current relevant situation. In this research, we will try to answer if the COVID lockdowns' impact on air temperature could be related to air quality. It is necessary to shed light on the relationship between the shutdowns and air temperature, especially during March, April, and May, but also during later months due to the potential lagged effects. Therefore, the main goal of our research will be to assess the records of air temperature and air quality during the whole of 2020 (with special attention to March, April and May) compared to past reference years (30 years for air temperature and 10 for air quality), discussing the possible effects of the reduction of activities (e.g., tourism and transport) due to the different lockdowns. We hypothesize that it is possible to close the debate of the impacts of the COVID-19 pandemic on the atmospheric conditions in 2020 not by strictly focusing on the lockdown, but on other global-scale dynamics.

2. Materials and Methods

2.1. Study Areas

All five selected cities registered more than 350,000 inhabitants and are mapped in Figure 1. The most populated urban areas (Figure 2A) were Madrid and Barcelona, with more than 3.3 million and 1.6 million inhabitants, respectively, followed by Valencia (800,215 in 2020), Sevilla (691,395 in 2020) and Málaga (578,460 in 2020). They were characterized by high population densities, with Barcelona reaching almost 17,000 inhabitants per km^2 (Figure 2B). The lowest value was registered in Málaga (1464 inh/km^2) in 2020. The rest ranged between ≈4500 (Sevilla) and ≈5900 (Valencia) in 2020. In general, the populations of these cities were highly affected by an intense aging process, with the major groups registered between 40–44 and 45–50 years old (Figure 2C). In almost all cities, the older population (65–80-years old) was more numerous than the children group (<14 years-old).

Figure 1. Map representing the localization of the sampled cities within Spain.

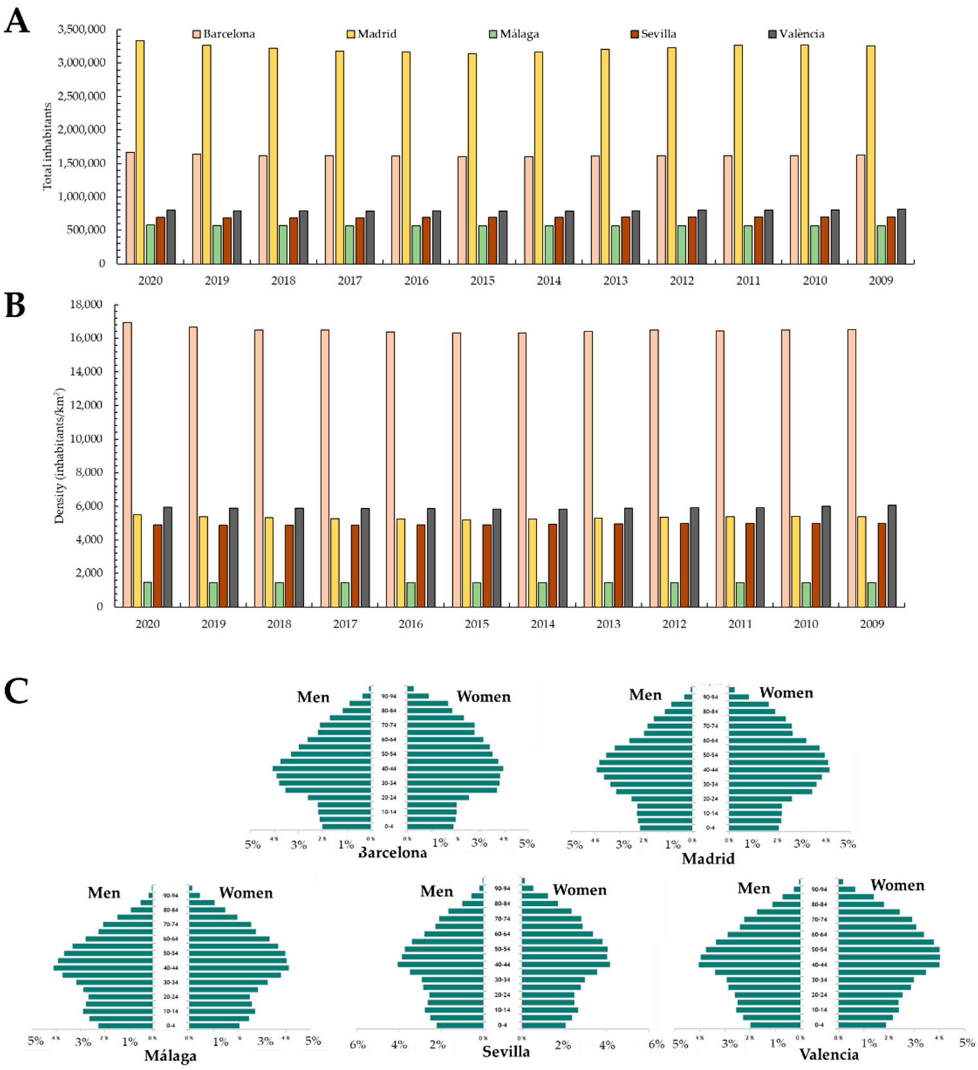

Figure 2. Demographical characterization of the five most highly populated cities in Spain. (**A**) Total population. (**B**) Density. (**C**) Population pyramid. Source: Instituto Nacional de Estadística (INE; Spanish National Statistics Institute).

2.2. Data Sources and Treatment

In this research, we considered five of the most populated cities in Spain in 2020 (Source: Instituto Nacional de Estadística –INE-; Spanish National Statistics Institute): Barcelona (Vall d'Hebrón 41°25′38.02″ N, 2°08′32.56″ E), Madrid (La Castellana, 40°26′23.61″ N, 3°41′25.34″ W), Málaga (El Atabal, 36°43′46.15″ N, 4°27′55.59″ W), Sevilla (Torneo, 37°23′51.74″ N, 6°00′02.92″ W) and Valencia (Politécnico, 39°28′46.46″ N, 0°20′14.84″ W).

Out of the six most populated cities in Spain, Zaragoza could not be analyzed due to insufficient data (just one year, 2019, in addition to 2020). We extensively analyzed five urban climate stations with long and complete data series, made available by the Spanish Ministry for the Ecological Transition and the Demographic Challenge (MITECO), which is the department of the government of Spain responsible for developing government policy on the fight against climate change, prevention of pollution, and protecting natural heritage, biodiversity, forests, sea, water and energy for a more ecological and productive social model (https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/atmosfera-y-calidad-del-aire/calidad-del-aire/evaluacion-datos/datos/Datos_2001_2018.aspx) (accessed on 18 March 2021). These data belong to five climate stations throughout Spain in highly populated urban areas with the remarked human activities with (1) daily air temperature data organized by average, minimum and maximum values for the last 30 years (1930–present-day) and (2) diverse pollutants, including O_3, NO_2, SO_2, CO, PM_{10} and

$PM_{2.5}$ for the last 10 years. Despite this, for the Andalusian cities (Málaga and Sevilla), the dataset had to be completed using temperature and pollutant values from the global quality platform air data (https://aqicn.org/data-platform/register/) (accessed on 18 March 2021), Red de Información Ambiental de Andalucía for Málaga and Sevilla (REDIAM) and Tutiempo.net (https://www.tutiempo.net/clima/espana.html) (accessed on 18 March 2021). Considering the temporal and spatial representability of this approach, it was only valid for the near-urban environment of the sampled climate stations and surrounding areas with similar environmental conditions. They were the representative urban stations located in non-green areas with the longest and most complete available data. The interpolation procedure, and thus the extension to the rest of the city, was carried out due to the high difference in data between the purely urban stations and the stations located in green areas. However, there was no reason to think that urban areas close to green areas were less polluted than fully urban ones, based on the data consulted in this study. Therefore, the climate stations with the maximum available pollution values were used, and in some cases such as Valencia, Malaga or Sevilla, they were the only ones available with all the variables analyzed.

The data was refined, eliminating stations that, in many cases, did not have more than one year of information or whose measurement variables were scarce. Even so, daily data for some variables (such as $PM_{2.5}$) were only available at two stations (Madrid and Valencia). The number of stations in Spain is very high—117 municipalities with data related to the variables analyzed and with several measurement stations in the case of large cities—however, the series was very short or incomplete in many cases, with numerous gaps that were often impossible to fill with nearby climate station. This is the fundamental reason why data were available from a few stations once the statistical purification process had been carried out. The data corresponding to all the variables were analyzed statistically using Excel (Windows) and SPSS v.23 (IBM, USA). Measures of the centrality and dispersion, average, maximum and minimum of the air temperature and pollutants were estimated for each city. In order to observe the trends between the air temperature and air quality changes for the last 10 years and 30 years, and to discard or assume any possible assumptions due to the COVID-19 pandemic and lockdown, all the data were compared in tables showing the mean values.

3. Results and Discussion

3.1. Air Temperature during 2020 and Reference Years in Highly Populated Cities in Spain

In Figure 3, the minimum, maximum and average temperatures are depicted. In addition, in Table 1, the comparison of a short period (2020 and, specifically, in March, April and May 2020) with long-term series (10 and 30 years, and average values in March, April and May) were summarized. The climate station located in Madrid registered average temperature values in 2020 of 16.05 °C, which were −0.7 °C with respect to the 10-year data series and the same as the 30-year data series. During the lockdown in March and April, colder months were registered, and only a warmer May was found. In Barcelona, the average temperature recorded in 2020 was 17.09 °C, being up to 0.61 °C warmer than during the last 30 years and 0.18 °C warmer during the last 10 years. Contrary to Madrid, in Barcelona, March, April and May 2020 were warmer than the average. Málaga and Sevilla, both of which are in southern Spain, showed higher average temperatures. Paying attention to Málaga, only April 2020 was colder than the long-term series. On the other hand, Sevilla recorded higher temperatures in March, April and May. Finally, in Valencia, 2020 registered an especially warm year, with temperatures +1.21 °C (30 years of data). Additionally, from March to May, warmer months were found in 2020 when compared with the long-term data series.

Table 1. Comparison of air temperature values (°C) in 2020 for the 10 and 30 year data series. TMax = maximum temperature; TMin = minimum temperature; Av.T = average temperature; and ± = standard deviation.

		TMin	TMax	Av. T
Madrid	2020	8.94	22.24	16.05
	10 years	9.92 ± 0.54	21.69 ± 0.85	16.75 ± 0.81
	30 years	9.53 ± 0.84	21.15 ± 0.77	16.05 ± 0.61
	Mar-20	5.18	16.62	11.16
	Av. March	5.1 ± 1.12	16.43 ± 2.06	11.4 ± 1.68
	Apr-20	8.02	19.53	13.49
	Av. April	7.26 ± 1.36	18.83 ± 2.14	13.73 ± 1.79
	May-20	10.82	26.84	19.35
	Av. May	10.87 ± 1.43	23.57 ± 2.21	18.27 ± 2.01
Barcelona	2020	11.44	22.37	17.09
	10 years	12.6 ± 0.47	21.15 ± 0.50	16.91 ± 0.37
	30 years	12.6 ± 0.68	20.81 ± 0.67	16.48 ± 0.9
	Mar-20	7.18	17.77	12.69
	Av. March	8.04 ± 0.88	16.51 ± 0.96	12.14 ± 0.72
	Apr-20	9.63	19.83	15.2
	Av. April	10.29 ± 1.30	18.55 ± 0.86	14.26 ± 0.86
	May-20	13.99	25.69	19.81
	Av. May	13.74 ± 1.41	21.72 ± 1.40	17.58 ± 1.19
Málaga	2020	15.97	23.12	19.05
	10 years	14.64 ± 0.44	23.94 ± 0.45	18.66 ± 0.36
	30 years	14.13 ± 0.66	23.55 ± 0.55	18.73 ± 0.5
	Mar-20	11.96	18.91	14.87
	Av. March	10.1 ± 0.88	19.6 ± 0.92	14.8 ± 0.70
	Apr-20	13.94	19.01	16.18
	Av. April	11.8 ± 1.21	21.8 ± 1.01	16.7 ± 0.94
	May-20	17.59	24.1	20.77
	Av. May	14.8 ± 1.03	24.6 ± 1.01	19.7 ± 0.94
Sevilla	2020	14.03	26.01	19.64
	10 years	13.11 ± 0.44	25.94 ± 0.67	19 ± 0.38
	30 years	12.93 ± 0.7	26 ± 0.54	19.32 ± 0.66
	Mar-20	10.31	21.16	15.4
	Av. March	9.18 ± 1.04	21.93 ± 1.98	15.52 ± 1.45
	Apr-20	12.33	22.28	17.17
	Av. April	11.17 ± 1.42	24.16 ± 1.72	17.67 ± 1.53
	May-20	16.76	29.86	22.96
	Av. May	14.32 ± 1.21	28.27 ± 2.07	21.44 ± 1.68
Valencia	2020	13.61	25.77	18.6
	10 years	12.45 ± 0.63	23.55 ± 0.66	18.19 ± 0.42
	30 years	12.4 ± 0.61	23.27 ± 0.63	17.74 ± 0.58
	Mar-20	10.11	19.26	14.47
	Av. March	7.73 ± 1.13	19.46 ± 1.5	13.44 ± 1.18
	Apr-20	11.76	23.25	16.11
	Av. April	10.02 ± 0.91	21.44 ± 1.18	15.68 ± 0.98
	May-20	15.7	29.05	21.19
	Av. May	13.51 ± 1.25	24.7 ± 1.29	19.15 ± 1.16

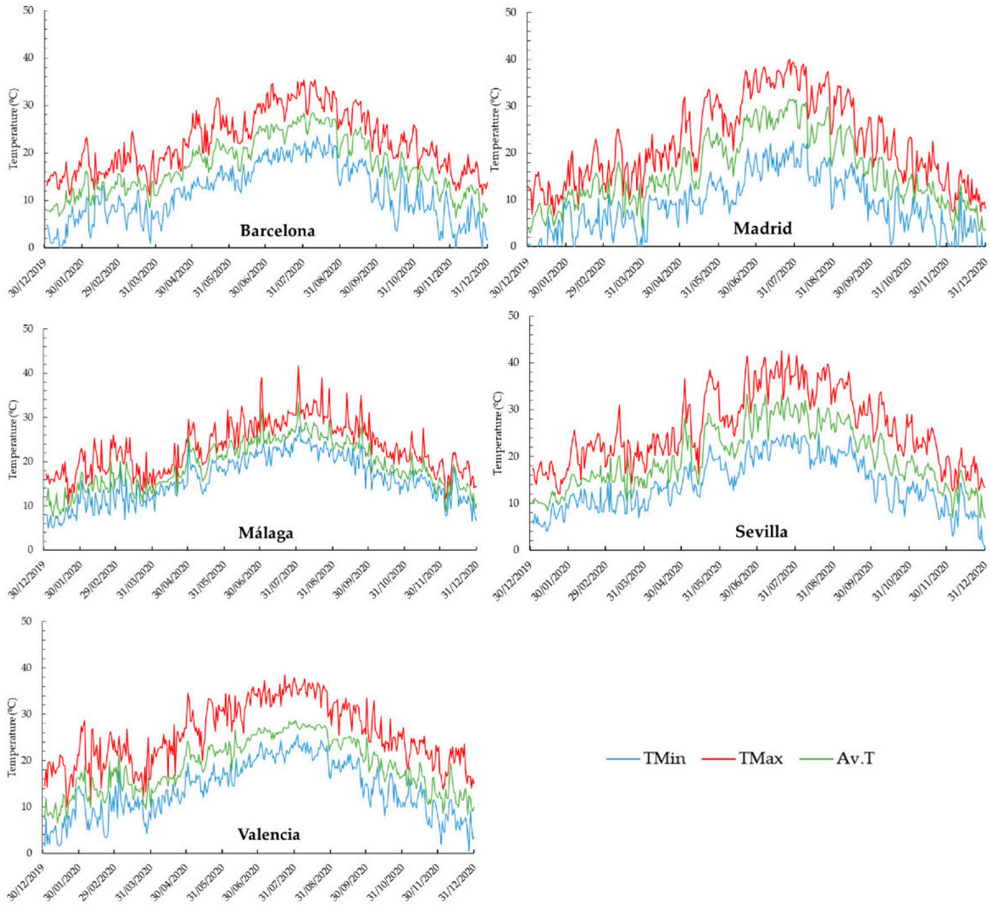

Figure 3. Atmospheric changes during 2020 in Barcelona, Madrid, Málaga, Sevilla and Valencia, depicting the average temperatures (Av.T), maximum temperatures (TMax), minimum temperatures (TMin).

In general, an increase in air temperature in 2020 was found when compared with both the 10 and 30-year data series. This agrees with all the reports related to the IPCC panels (e.g., [30,31]) from recent investigations related to climate change in Mediterranean cities and all over the world [32]. Our results agree with previous studies related to heat islands and aridity published in these cities (e.g., [33–39]), although we have to also consider that less commuting during the shutdown may have resulted in less heat waste, resulting in a slightly reduced urban heat island effect and thereby reducing local temperatures. Therefore, it is difficult to confirm that the COVID-19 pandemic and lockdowns had an impact on air temperatures in the highly populated cities in Spain in 2020 due to the reduction of human activities and, subsequently, transport. Therefore, responding to this continued increase, we state that policymakers should focus on developing more green policies if, as some authors affirmed, there is a clear correlation with COVID-19 spreadability [40–42].

3.2. Air Quality during 2020 and Reference Years in Highly Populated Cities in Spain

Although the analysis focused on O_3, NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$ (Figure 4), it was not possible to perform a comparative assessment concerning CO in Madrid, Valencia and Barcelona, because only Seville and Malaga had a series of previous and valuable data. Additionally, $PM_{2.5}$ could only be analyzed in Madrid and Valencia, as there were no data for 2020 on this variable. In general, for all the stations, an overall reduction in pollution levels during the time of confinement (from March 15 to May 10, although generalized to March, April and May) was found. This decrease also resulted in changes reflected in the annual values being the lowest in the series (10 years), although there were important particularities in each of the parameters which could show negative impacts related to COVID-19 spreadability [43].

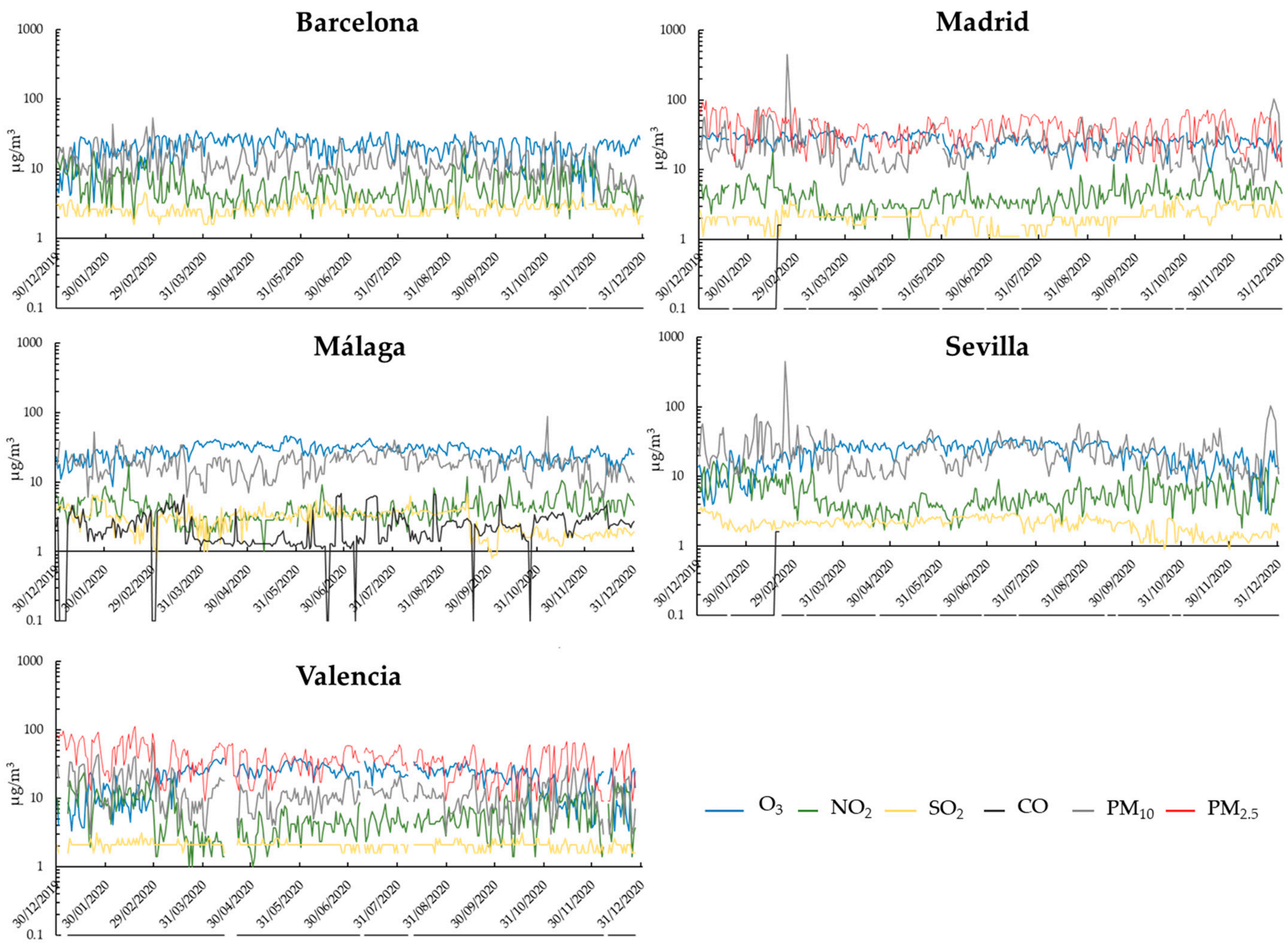

Figure 4. Atmospheric changes during 2020 in Barcelona, Madrid, Málaga, Sevilla and Valencia.

It is well known that tropospheric O_3 at higher levels can cause premature human mortality [44]. Tropospheric O_3 originates from (1) natural emission from lightning and the biosphere; (2) chemical emission, namely solar radiation; and (3) atmospheric transport [45]. Some authors also mention that the concentration of tropospheric O_3 can occur in areas with a significant presence of precursors (especially NOx gases such as NO_2 and volatile compounds), in addition to high solar radiation, so it is quite variable throughout the day [46]. O_3 is a direct greenhouse gas understood as the main cause of anthropogenic photochemical smog, and it is responsible for an increase in global warming between 5% and 12% [47].

According to the Ministry for the Ecological Transition and the Demographic Challenge (MITECO.gob: https://www.miteco.gob.es/images/es/informeevaluacioncalidadaireespana2019_tcm30-510616.pdf) (accessed on 18 March 2021), the minimum O_3 level in Spain to prevent or reduce harmful effects on humans is 120 µg/m^3, reaching the alert threshold at 240 µg/m^3. Although the annual reports of previous years indicated a habitual surpassing of these thresholds, especially in the south of Spain, the analyzed data indicated daily maximum values that were around 40 µg/m^3 for all cities (Table 2). The air quality index (https://aqicn.org/data-platform/register/) (accessed on 18 March 2021) classifies values below 50 µg as good, while the threshold for moderate ranges between 50 µg/m^3 and 100 µg/m^3. The city with the highest average values in 2020 was Malaga (27.9 µg/m^3, with a maximum of 46.5 μg/m^3). Every month, none of the cities exceeded the average values reached in previous years for March, April or May. The greatest reductions for the average values occurred in Madrid, Barcelona and Valencia, with figures around 75% below the average. Concerning annual levels, a drastic reduction occurred in Valencia, with values of 55.9% compared with the annual average. On the other hand, the lowest reduction occurred in Seville (80.8%). These differences between these two cities could be related to their more industrial characteristics. Specifically, it was observed that Valencia had a large air quality index reduction. This could be explained by Valencia possibly having more manufacturing plants or more commuters than the other cities, and therefore, the shutdown had a larger impact. In addition, we considered that the older population affecting the more elevated amount of the potential population's ability to work in Valencia may be related to the decrease in activities and an increase in air quality. However, longer analyses should be conducted to understand why they had such a large reduction while Sevilla registered the lowest reduction.

Table 2. Comparison of tropospheric ozone values in 2020 and the 10 years of data series. Av. = average.

Values (μg/m^3) (*)	Madrid	Barcelona	Valencia	Sevilla	Málaga
2020	20.94	21.05	21.14	21.89	27.91
Annual values (10 years)	30.61 ± 0.79	34.88 ± 1.26	37.81 ± 1.75	27.1 ± 0.86	37.95 ± 2.57
Mar-20	22.61	24.45	22.97	24.25	28.93
Av. March	31.8 ± 2.59	31.37 ± 4.52	33.91 ± 3.01	26.44 ± 2.19	34.81 ± 4.53
Apr-20	26.06	29.95	29.15	26.5	35.15
Av. April	36.34 ± 3.08	36.46 ± 2.88	38.73 ± 2.36	29.65 ± 2.32	37.82 ± 5.13
May-20	28.64	27.19	28.74	28.37	34.81
Av. May	39.07 ± 1.84	36.36 ± 1.38	38.51 ± 3.26	33.26 ± 2.18	41.42 ± 2.96

(*) MITECO (ica.miteco.es) use these units.

Nitrogen dioxide (NO_2) is a respiratory toxic gas that, in the outside air, is mainly derived from the oxidation of nitric oxide (NO) coming from vehicles in urban areas (especially diesel), but also from heating appliances and electricity generation [48]. For NO, recommended hourly limits of 200 μg/m^3 and alert thresholds of about 400 μg/m^3 for reducing human health issues and costs were highlighted by several scholars in highly populated cites [49,50]. However, the Spanish Directive 2008/50/CE and RD 102/2011 lowered these values to 30 μg/m^3 as a critical level for the protection of vegetation. The average values of the series (Table 3) indicate that Madrid was the city in which the highest values were normally reached (25.58 μg/m^3). Meanwhile, Málaga did not reach 10 μg/m^3 (8165). Nevertheless, throughout 2020, the most drastic reductions overall were registered in Sevilla (which reduced its average emissions to 35.8% of the average of previous years) followed by Madrid (47.7%). On a monthly level, it should be noted that, except Madrid, important decreases for the averages of the months of confinement were recorded, especially during April. Therefore, we observed a decrease in pollution due to the reduction of activities [51]; although, this did not reflect lower COVID-19 spreadability [52,53]. NO content is exponentially increased with temperature [54] which, observing the air temperature results obtained above, could be worrying.

Table 3. Comparison of nitrogen dioxide values in 2020 and the 10 years of data series. Av. = average.

Values (μg/m^3)	Madrid	Barcelona	Valencia	Sevilla	Málaga
2020	12.2	11.66	6.15	5.78	5.63
Annual values (10 years)	25.58 ± 2.03	13.79 ± 0.64	10.03 ± 2.56	16.18 ± 1.86	8.17 ± 0.54
Mar-20	10.12	10.97	4.61	5.11	5.05
Av. March	24.99 ± 1.72	14.91 ± 3.02	12.13 ± 2.82	16.37 ± 2.15	7.46 ± 1.38
Apr-20	5.29	6.7	2.55	3.13	2.62
Av. April	21.45 ± 1.09	13.71 ± 1.78	9.17 ± 3.0	15.85 ± 0.58	7.33 ± 0.44
May-20	5.96	7.08	3.67	3.59	4.07
Av. May	21.22 ± 2.53	12.75 ± 1.43	6.99 ± 1.56	15.01 ± 2.2	7.41 ± 1.32

MITECO (ica.miteco.es) use these units.

Sulfur dioxide (SO_2) showed uneven behavior during the time of confinement and throughout 2020, for example, in Barcelona, Valencia and especially in Sevilla, which almost showed their average values (Table 4). What is also noteworthy is the high concentration of this gas in Malaga, which quintupled Barcelona, although it is not a particularly industrial city (the data collection station is located next to a water treatment plant but far from the city's thermal power plant). Its maximum values were close to 20 $\mu g/m^3$ on average in 24 h. In the past, the main anthropogenic source was the burning of fossil fuels (coal and oil) used in heating, electricity generation and thermal combustion vehicles [55,56], which during the lockdown in Spain should be not considered, since the diesel fuel in Europe today is virtually sulphur-free. Therefore, it could be more related to the use of home electricity demands [57].

Table 4. Comparison of sulfur dioxide values in 2020 and the 10 years of data series. Av. = average.

Values ($\mu g/m^3$)	Madrid	Barcelona	Valencia	Sevilla	Málaga
2020	2.58	1.05	2.09	2.07	2.93
Annual values (10 years)	3.68 ± 1.1	1.05 ± 0.13	1.94 ± 0.29	1.23 ± 0.14	5.29 ± 0.61
Mar-20	2.13	1.08	2.12	2.19	2.89
Av. March	3.9 ± 1.86	0.51 ± 0.29	2.79 ± 2.25	1.28 ± 0.31	5.51 ± 2,13
Apr-20	2.15	1	2.14	2.13	2.73
Av. April	3.23 ± 1.63	0.53 ± 0.09	1.77 ± 0.57	1.13 ± 0.12	5.63 ± 2.17
May-20	2.44	1.02	2.18	2.28	3.34
Av. May	3.29 ± 1.67	0.57 ± 0.26	1.6 ± 0.35	1.19 ± 0.49	5.32 ± 1.84

MITECO (ica.miteco.es) use these units.

Finally, regarding the data obtained for $PM_{2.5}$, PM_{10} and CO, the available data made them impossible to be compared in all the cities and years. Although $PM_{2.5}$ and PM_{10} are constituted naturally by dust particles, sea salts, pollen or spores, they also have a clear urban origin in emissions from engine combustion and anthropic volatile organic compounds and construction with negative impacts on human health [58,59]. Recently, several authors observed a clear relationship between an increase in $PM_{2.5}$ and PM_{10} and an increase in air temperatures, due to their ability to absorb radiation and serve as a medium for chemical reactions. This is also the case for CO, which can be combined with oxygen to increase the generation of greenhouse effects. In the case of our analyzed data, a generalized decrease in the cases studied was noted. The local peculiarities derived from a longer period of rain in certain seasons could coincide with the confinement, although they were not observed at a general level in all seasons. Therefore, it can be concluded that there was also a reduction during 2020 and especially during the lockdown. Our results agree with other countries, particularly urban areas in China studied by several scholars during the last decade [60–62]. The most recent studies also confirmed that $PM_{2.5}$ and PM_{10} showed the most significant changes during the first part of 2020 during the COVID-19 pandemic, as some scholars demonstrated in California [63] and the megacities of New Delhi [64] and Baghdad [65] due to the reduction of activities. It is worth highlighting that an investigation conducted in the three major French cities (Paris, Lyon and Marseille) demonstrated the possible correlation between these pollutants and deaths due to COVID-19. They considered the hypothesis that predetermined particulate concentrations could foster COVID-19 and make the respiratory system more susceptible to this infection [66]. It is also plausible that reduced pollution due to lockdowns would lead to short-term warming as a result of more incoming sunlight, rather than cooling. Several authors reported this short-term cooling effect of aerosol-causing pollution (e.g., [67]). Moreover, it would be interesting to see whether solar radiation, cloudiness or visibility data are available for these stations in the future to substantiate the effect of reduced pollution on sunlight reaching the surface. Therefore, we consider that it is key that green policies and strict regulations of contaminants spread out to the atmosphere must be further developed to reduce the potential increase in COVID-19 infections and guide recovery [68,69].

4. Conclusions

In this research, a complete assessment of 2020 was carried out to decipher the possible relationship between air quality and temperature and the reduction of activities due to the COVID-19 pandemic and different lockdowns in some of the major Spanish cities (Barcelona, Madrid, Málaga, Sevilla and Valencia). We conclude that the effects of the lockdown (reduction of activities and social communication) were non-significant in the main Spanish cities in terms of reductions in the average levels of pollution throughout 2020 in five representative urban climate stations. These results demonstrated that an obvious decrease due to the shutdowns was not discernible and, in fact, the temperature increased in 2020 (due to climate change, among other factors). In this research, we cannot affirm if there a way of confirming if the increase in 2020 was not as large as what would have been predicted before COVID. Maybe the increase is still there but somewhat muted. This is a very interesting hypothesis. To date, only models could predict the possible increase or decrease in temperatures during 2020 without the pandemic. However, climate models could only approximate the irregularity of the Mediterranean climate and not allow us to infer any realistic conclusion. Despite this, some parameters continued to exceed the average levels recommended by the WHO on specific days in practically all the considered variables, especially in the case of PM_{10}. Despite the reduction in measured urban pollutants during the lockdown, our results were unable to establish even a minimal relationship with air temperatures (average, minimum, maximum, daily, monthly or annual) and instead showed the continued upward trend that has been registered for some time—even for decades—in all worldwide cities. Therefore, considering recent studies highlighting the relationships between air pollutants, temperature and spreadability of COVID-19, green policies must be further imposed in urban cities.

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