Air and Water Quality Improvement during COVID-19 Lockdown

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Abstract: COVID-19 pandemic forced many countries to adopt lockdown measures, temporarily closing factories, diminish maritime traffic and reducing the mobility of people in the cities. Analysis from the Tropospheric Monitoring Instrument (TROPOMI) and Ocean and Land Colour Instrument (OLCI) on board Europe's Sentinel-5P, 3A/B respectively, for the first wave of the COVID-19, have shown a substantial improvement in air and water quality. More specifically, since COVID-19 lockdown until the end April, Lisbon and Porto were at their lowest PM10 levels of about 20% and a drop of 33% in 2 years, while Madrid had a significant drop since lockdown with vales significantly below 2018 levels but still close to 2019 levels. In terms of NO_2 levels, Lisbon had an historical minimum of the last 2 years, dropping more than 40% during most of April 2020. Finally, Madrid had 2-year lowest level of more than 30% since lockdown. Concerning the water quality in the Portuguese coastal waters, it was verified an increase in water transparency since confinement started until May, accordingly to the Total Suspended Matter (TSM) indicator. From February to March, March to April and April to May there was a reduction in TSM levels of 17%, 37% and 53% respectively.

1 INTRODUCTION

The novel coronavirus disease, COVID-19, became a pandemic in 11th March 2020. This virus was firstly identified in the city of Wuhan, China, in December 2019 and causes acute respiratory problems. In order to protect the population from this pandemic, many countries adopted lockdown measures, leading companies to adapt the functions of their workers in teleworking or lay-off mode. As a consequence, there was a drastic reduction in the air traffic, motor traffic, and industrial activity. All of these activities have an impact in the air and water quality. According to the World Health Organization, air pollution kills an estimated seven million people worldwide every year and that 9 out of 10 people breathe air containing high levels of pollutants (World Health Organization, 2020). The urban centres of large cities are characterized by a high population density, high motor vehicle traffic, and intense industrial activity, so they are naturally areas with high levels of air and water pollution. Quantifying the status of pollution during the lockdown period is an important task for researchers to understand the effect of the COVID-19 spread on the environment in the short- and long-term.

The most well-known pollutants from the troposphere include ozone, carbon monoxide, nitrogen dioxide and sulfur dioxide. Specifically, nitrogen dioxide (NO_2) is generated by vehicles, heavy industry and power plants. The EU Ambient Air Quality Directives limits the concentration of 200 $\mu g/m^3$ (not to be exceeded more than 18 hours per year) and annual average below 40 $\mu g/m^3$. The main effects of breathing NO2 relates to the increase of probability of respiratory problems as in high doses it could inflame the lining of the lungs and reduce immunity to lung infections, causing problems like coughing, colds and bronchitis.

Concerning aerosols, the levels of particulate matter aerosols < 10µM (PM10) have a significant impact in the air quality. These particulate matter aerosols are microscopic particles of solid or liquid matter suspended in the air and are measured in g/m^3. The main sources of these aerosols include i) human origin such as industrial processes and product use, agriculture, commercial, residential and households; ii) natural our semi-natural sources such as desert dust, biomass burning and sea salts. The EU Ambient Air Quality Directives limits the daily average (with no more than 35 days per year) below 50 $\mu g/m^3$ and annual average below 40 $\mu g/m^3$. PM10 affects

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cardiopulmonary and respiratory health, the immune system and in last instance can cause lung cancer. Recent studies found evidence of SARS-Cov-2 RNA on PM10 air samples and other studies are pointing towards a relation between PM10 and increased mortality rate. The reduction in the air traffic, motor traffic, vessel traffic and industrial activity naturally has a positive impact on the level of the pollutants previously referred in the troposphere. This was confirmed on the 2nd March 2020 by NASA and ESA, that monitored the levels of NO_2 in China, from 1st January until 25th February and detected significant decreases in these levels. According to the Ministry of Ecology and Environment, China, the air quality went up 11% in the category ‘good’ in as many as 337 cities (Henriques, 2020)

As already mentioned, maritime traffic also had a sharp decrease during the lockdown, contributing to an improvement in the water quality in the oceans. Ocean health has a key role in the human life, as it produces half of the world’s oxygen, absorbs 50 times more carbon dioxide than the atmosphere, regulates the climate, provides food and many other human demands.

One of the indicators of water quality is the Total Suspended Matter (TSM) levels, measured in mg/L, which indicate the amount of suspended particles in water bodies. Thus, it can be considered a parameter to evaluate the turbidity of water and its health. Some of these particles are present naturally in river and sea waters, such as plankton, fine plant debris and minerals, while others stem from human activity (organic and inorganic matter). As TSM levels increase, the appearance of the water becomes cloudier as light penetration decreases which has a negative impact on river and sea biology and can affect photosynthesis with important effects on biogeochemistry and life itself. High TSM levels can also clog fish gills, either killing them or reducing their growth rate. During the lockdown, it was verified that the surface water quality of the Vembanad Lake in India, had major improvements in the Suspended Particulate Matter (SPM) (Yunus et al., 2020).

With a visible trend towards improving environmental qualities during the COVID-19 pandemic shown by several research groups, the Earth Observation laboratory (EO lab) from Atlantic International Research Centre (AIR Centre) was also interested in monitoring the environmental impacts during lockdown by monitoring air and water quality in Portugal (Lisbon and Porto) and Spain (Madrid) between the months of March and May 2020 corresponding to the first wave of the pandemic. The results were produced through the use of Copernicus data and services.

2 COPERNICUS IN SUPPORT OF AIR AND WATER QUALITY MONITORING

Copernicus is the European Union's Earth Observation Programme, managed by the European Comission. It is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Océan. With its Sentinels Constellation, Copernicus offer information services in six thematic lines: Atmosphere, Marine, Land, Climate Change, Security and Emergency. For air quality, Sentinel-5P and its instrument on board, TROPOspheric Monitoring Instrument (TROPOMI) offer quality data about key atmospheric species. The Copernicus Atmosphere Monitoring Service (CAMS) delivers Regional and Global Products based on data from Sentinel-5P related to air pollution and health, solar energy, greenhouse gases and climate forcing.

Sentinel-3A and 3B have on board the Ocean and Land Colour Instrument (OLCI), a visible imaging push-broom radiometer with 21 spectral bands from 400 to 1200 nm offer a large spectrum of type of data, related to ocean, atmosphere, and land. Some products range from water surface directional reflectance, algal pigment concentration, total suspended matter concentration, among others.

3 RESULTS AND DISCUSSION

3.1 Air Quality

Figure 1 depicts the timeline of NO_2 emissions during the COVID-19 outbreak in Portugal and Spain, images from European satellite Copernicus Sentinel-5P using TROPOMI (Tropospheric Monitoring Instrument). The images show a drastic reduction in NO_2 contamination levels due to reduced industrial activity, which helps mitigate the impact of the COVID-19 outbreak.

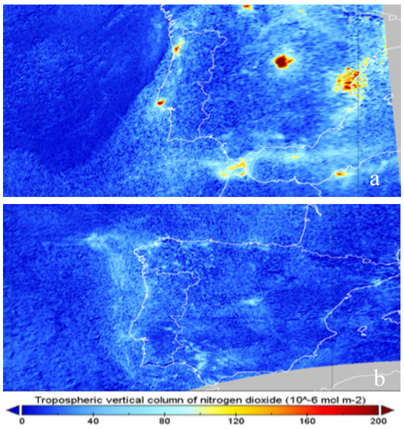

Figure 1: Tropospheric vertical column of nitrogen dioxide (NO_2) in the Iberian Peninsula in: a) 10th March 2020 and b) 28th March 2020.

A timeline of NO_2 emissions in detail for Portugal and Spain is presented in Figure 2, based on Regional Products from CAMS service, and generated for 13h UTC for several days, before and after the COVID outbreak in Portugal. The difference from this data to the data in Figure 1 is that the CAMS service digests hourly values into a model, in this case the Ensemble median, at the surface level, while data directly from TROPOMI is representative of the total air column. At the surface level and at a regional scale, NO_2 levels are expressed in $\mu g/m^2$. Results show a significant reduction in NO_2 contamination levels due to reduced industrial and other anthropogenic activity, both in Portugal and Spain.

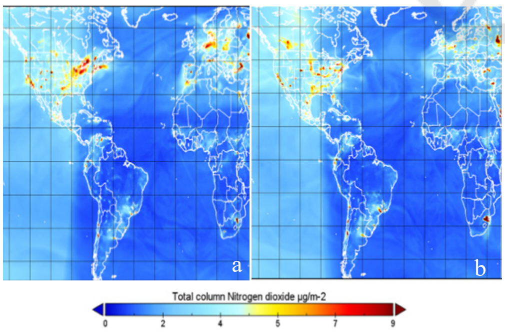

Figure 2: a) to b) – Total column Nitrogen Dioxide in air for 10-03-2020 and 31-03-2020, respectively, in Atlantic Regions.

Also, a less detailed analysis of NO_2 levels for 10th March and 31st March for the Atlantic Region was carried out and is presented in Figure 3. This analysis was generated through CAMS's Global Products, so the units are expressed in $\mu g/m^2$. More specifically, it is visible maritime traffic passing in the Strait of Gibraltar, which is a sign that maritime commercial activities continued to operate. Also, is possible to observe a reduction in Europe, the same is true to the USA but to a much less extent.

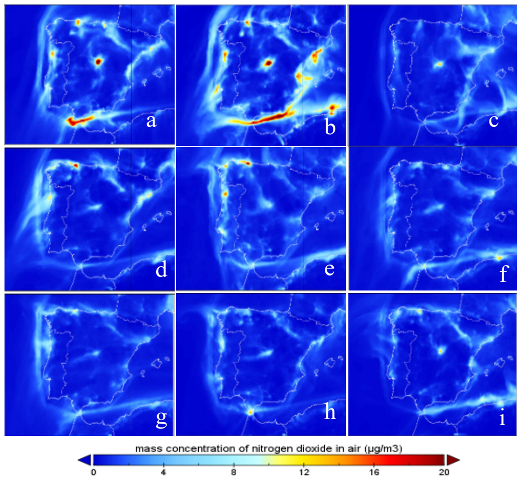

Figure 3: a) to b) – Mass concentration of Nitrogen Dioxide in air for 10-03-2020, 11-03-2020 (before COVID outbreak in Portugal); c) to i) 16, 18,20, 22,24,28-03-2020 and 1-4-2020 respectively (after COVID-19 outbreak).

In Figure 4, are presented yearly NO_2 emissions for Portugal and Spain, Lisbon, Porto and Madrid generated using a 7-day average for daily values determined at surface level and at 22h UTC, also using CAMS service. The approach consisted in verifying the regional NO_2 emission reduction for Portugal and Spain and, also, in analysing the trends for major cities within this territory. As expected, the NO_2 emissions for the whole region peak for lower values, however the curves behaviour dampens local anomalies that may be observed in specific urban areas, such as Porto city, as detailed below. In Portugal and Spain territory, in 2020, there is a reduction of approximately 26% for April 30 comparing with 2018 and 2019 and scaling for values above 40% in the first week of April.

At a local scale, on April 30 the NO_2 emissions are at their historical minimum since 2018 in Lisbon (reduction of approximately 4,8% for 2019 and 2018 and more than 40% in the first weeks of April) and Madrid (30,2% for 2019 and 45,5% for 2018). However, in Porto there is a significant drop in NO_2 emissions, but the current level is still above 2019 and 2018, which might be explained due to several factors such as a different rainy season. Similarly, as for the concentration of PM10, the concentrations of NO_2 in the air are lower since the lockdown due to COVID-19 in March for the three cities (20% for Lisbon, 30,7% for Porto and 50% for Madrid).

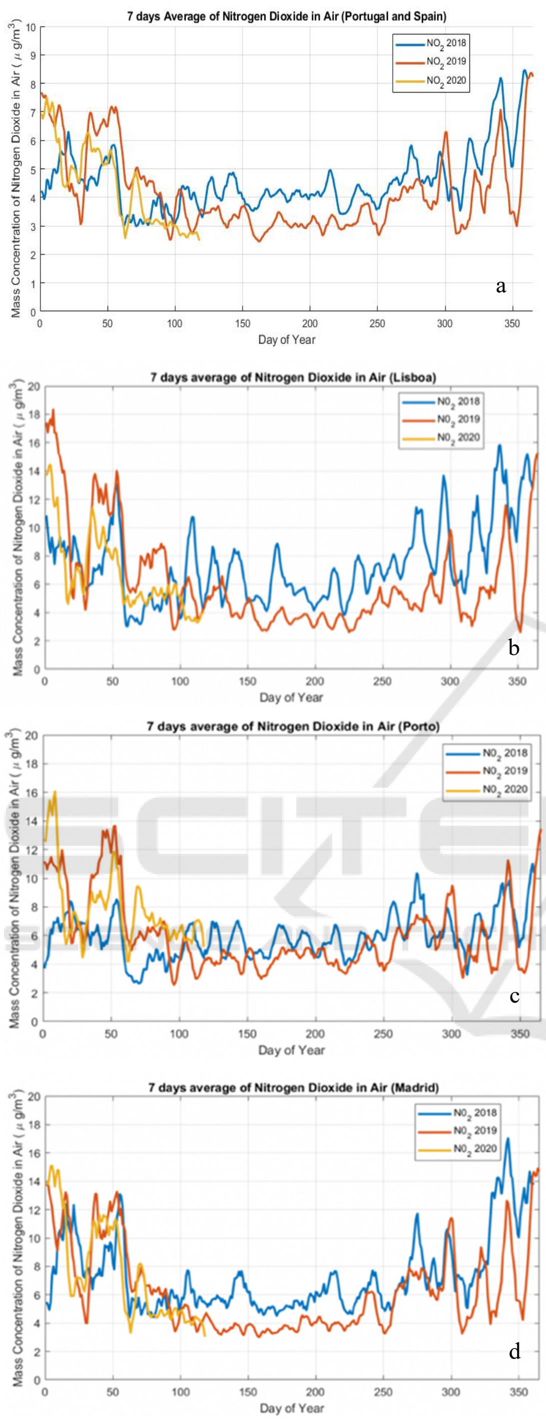

Figure 4: a) to d) - Historical mass concentration of Nitrogen Dioxide in air for Portugal, Spain, Lisbon, Porto and Madrid for 2018 (blue), 2019 (orange) and 2020 (yellow).

The concentration of PM10 was also analysed in the three cities for the period of January-April 2020 and compared with the same period in 2019 and 2018.

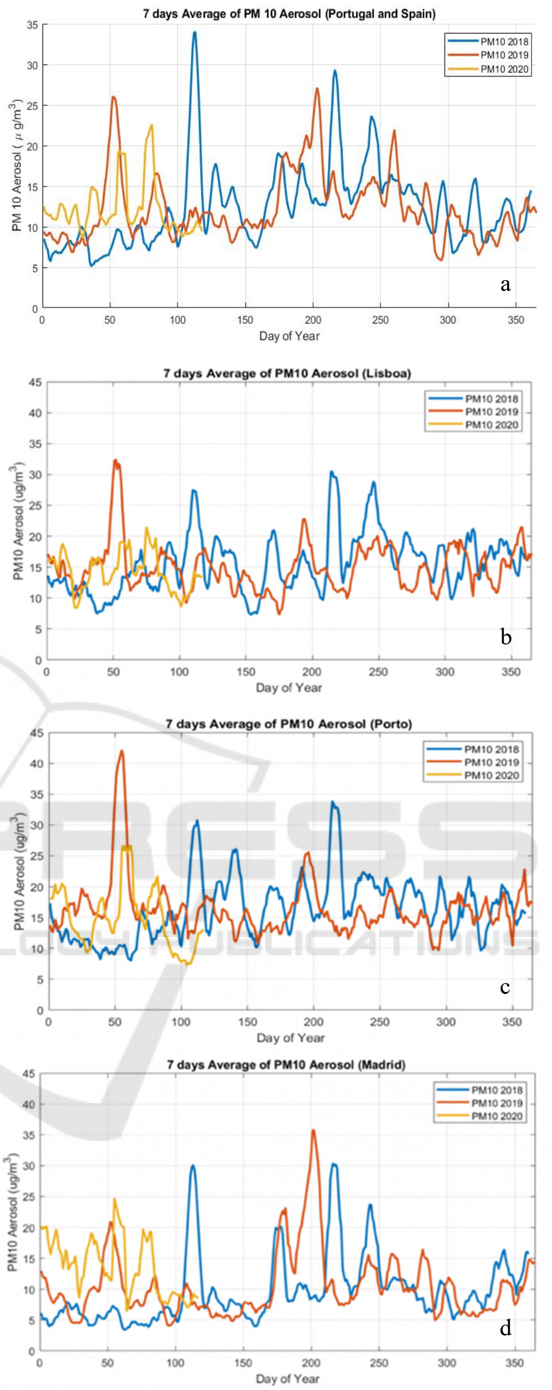

Figure 5: a) to d) - Yearly PM10 evolution in 2018 (blue), 2019 (orange) and 2020 (yellow) for Portugal and Spain, Lisbon, Madrid and Porto, respectively.

Comparing the results, it can be stated that there is a reduction of PM10 levels in April based on Portugal and Spain regional assessment. Comparing with the two previous years, the area registered reduction up to 24% in the two first weeks of April, that decreases for 18% by 30 April. At a local assessment, for Porto the PM10 levels are lower in 2020 than in the past two years for the end of March and April. For the last day analysed (30 April 2020) there is a reduction of approximately 22,9% for 2019 and 2018. For Lisbon, the PM10 levels are lower in 2020 than in the past two years in April, even though there is a slight increase in some days of analysis, matching the values of 2019, but then there was a further drop in PM10 levels (reduction of 20% for 2019 and 2018, April 30). In the case of Madrid, the reduction could only be verified from the second week of April, and even so, in 30th there was a slight increase of PM10 when comparing to 2019. The main conclusion verified for the tree cities is that the concentrations of PM10 in the air are lower since the lockdown due to COVID-19 in March (33,3% for Lisbon, 33,3% for Porto and 52,6% for Madrid).

All together, results from Figures 1-5 are concordant with the results stated by Mesas-Carrascosa et al., 2020 and Zhang et al., 2020.

3.1 Water Quality

The concentration of TSM has been analysed before and after COVID-19 pandemic to understand if any changes had occurred. The approach consisted of mapping TSM concentration on four dates, corresponding to a given day of the month before COVID-19 confinement (February 2020) and a given day of each month during confinement (March, April and May), as well as mapping the TSM differences between these dates. This study was carried out using the Water Full Resolution (WFR) level 2 data from Sentinel-3 OLCI sensor

The following pictures illustrate the TSM for a given day per month from February to May 2020. The dates have been chosen according to the best no-cloud images available.

The Image Differencing Change Detection method was applied using the software ARCGIS in order to visualise the positive and negative differences between the TSM along these months. Change detection involves quantifying temporal effects using multi temporal data sets. When the interest is to understand the changes over large areas and at frequent interval satellite data these methods are commonly used.

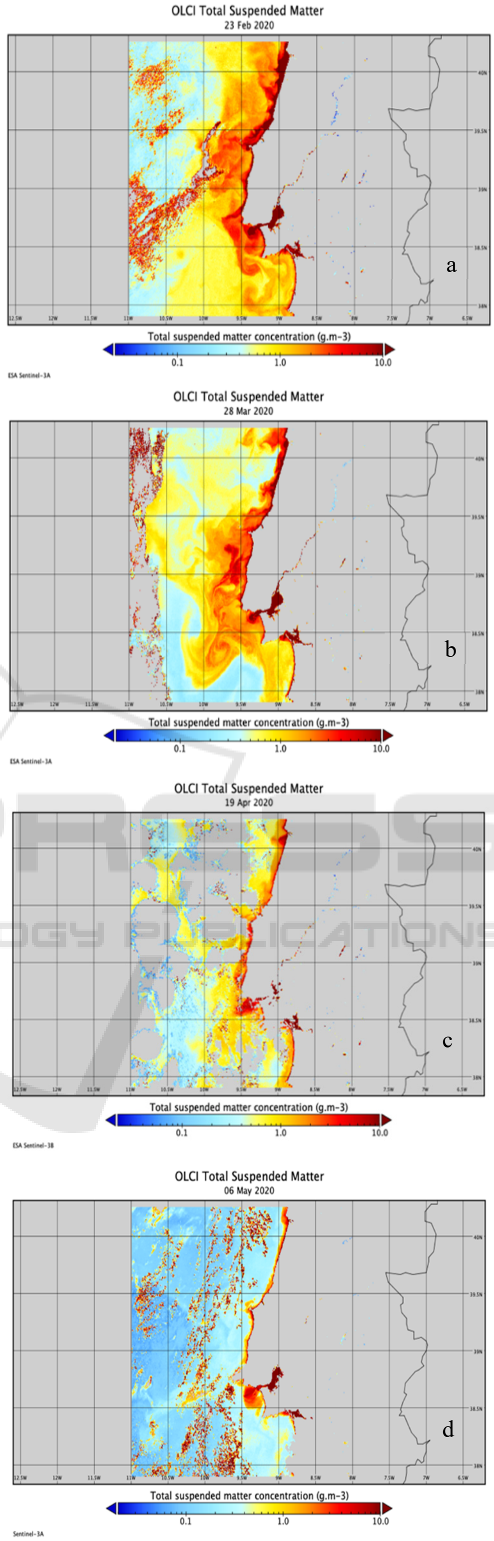

Figure 6: a) to d) - Total Suspended Matter for 23-02-2020, 28-03-2020, 19-04-2020 and 06-05-2020, respectively.

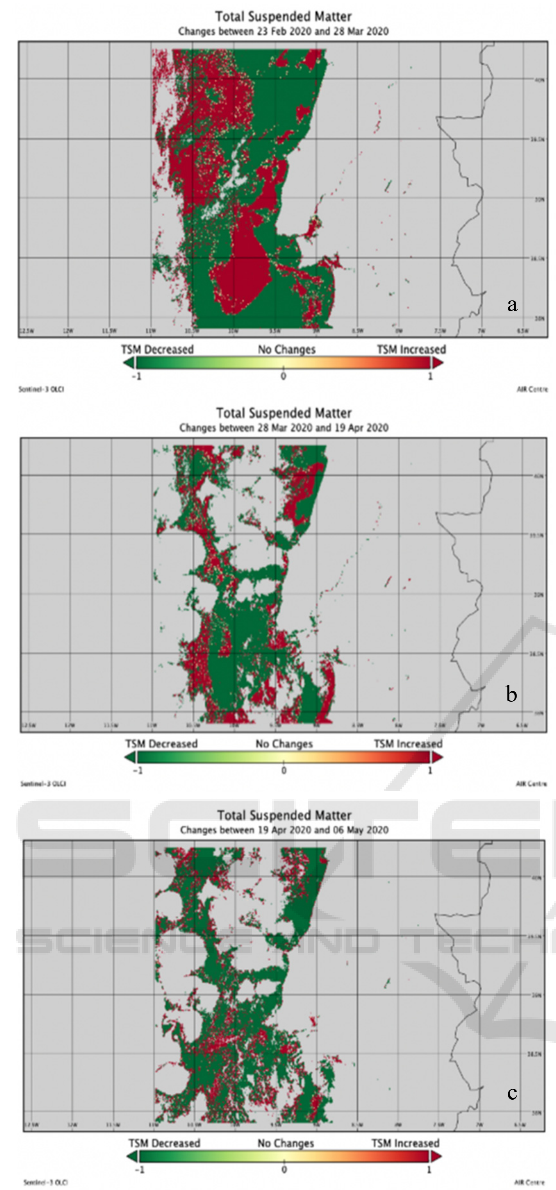

Figure 7: a) to c) Changes of TSM levels between 23-02-2020 and 28-03-2020, 28-03-2020 and 19-04-2020, 19-04-2020 and 06-05-2020, respectively.

The results suggest that there was a decrease on the TSM concentration from February to March, March to April and April to May of 17%, 37% and 53% respectively.

A similar approach was applied to compare the TSM fluctuation between the months of 2020 with the same fluctuation between the months of 2019 in order to understand if there was any natural pattern on these changes that can be affecting the results. In this case the same method was applied to the images from 2019 and the results of this approach are summarised in the chart below.

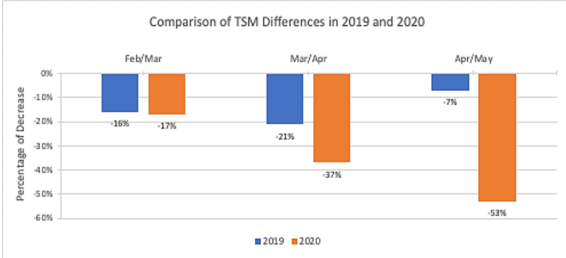

Figure 8: Percentage of TSM decrease between months in 2019 and 2020.

Although the TSM is not only a consequence of human activities (Fernández-Nóvoa et al., 2017), these results may indicate a pattern as a result of COVID-19 restrictions.

4 CONCLUSIONS

This study has used, in a first stage, Sentinel-5P and CAMS service to analyse the air quality in the territory of Iberian Peninsula, as well as assess in detail major cities within the region (Lisbon, Porto and Madrid), for a period from January 2018 to April 2020. On a later stage, the data from Sentinel-3A and 3B allowed the analysis of water quality during the months March, April and May 2020, in the Portuguese coast. Regarding the air quality, NO_2 and PM10 levels in the Iberian Peninsula were consistently lower comparing with analogous periods of late March and April of the two past years. In the majority of the analysed cities, it was observed a similar behaviour of the for the NO_2 and PM10 concentrations, except for a NO_2 in Porto that may result from local anomalies. One aspect be taken into account is that meteorological conditions such as wind, rain and seasonal variations of boundary layer have significant impact on the concentrations of these air quality parameters. Concerning TSM levels, the results suggest that there might be a pattern as a result of COVID-19 restrictions, but seasonal variations also play a role in this analysis, so it is required an analysis with a more extended timeline to infer about the role of COVID-19 pandemic in the transparency of the coastal waters. In 2020 the reduction of TSM concentration has been much more pronounced when compared with the same period of 2019, which, most likely, could be due to COVID-19 confinement.

As future work, it is necessary to consider a wider sample of previous years in order to identify seasonal patterns and better conclude about the local anomalies; also consider a cross-validation of these findings with local water sampling reports and results, as well with data from local atmosphere pollution sensors.

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