



Intercontinental Geoinformation Days

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Effect of first wave COVID-19 outbreak lockdown measures on satellite-based tropospheric NO₂ over Mersin Province, Turkey

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Keywords

Remote sensing
COVID-19
GEE
Sentinel 5P
NO₂

ABSTRACT

In recent years, greenhouse-trace gases pollution is one of challenging problems all over the world. Due to the coronavirus (COVID-19) epidemic in the world, almost all countries implemented some restrictions that reduced human activities in cities and industries. As a result of these restrictions, an opportunity occurred to monitor the changes in anthropogenic (human-made) air quality. Among the other air pollutants, NO₂ is one of the important trace gases on the atmosphere which can arise with anthropogenic and natural sources. This study investigated NO₂ pollution derived from Sentinel-5P satellite associated with the first wave lockdown of COVID-19 pandemic over Mersin city, located at the Mediterranean coast of Southern Turkey. The tropospheric NO₂ vertical column density (VCD) data were derived from TROPOMI instrument onboard the Sentinel 5P satellite, and Google Earth Engine (GEE) platform was used for the analyses. The results showed that the substantial 35 % reduction in NO₂ concentration was observed over Mersin when comparing the lockdown time in 2020 and the corresponding days in 2019.

1. INTRODUCTION

Nitrogen dioxide (NO₂), as one of six common air pollutants listed by World Health Organization (WHO) (Bert and Stephen 1999; Oo et al. 2021), is a short life pollutant in the atmosphere (Dutta et al. 2021). Moreover, its concentration rises due to the increase in the anthropogenic and natural sources of emission comprising industrial activities, the fossil fuel combustion in land-water-space transports and thermal power plants (Center 1999; Hilboll et al. 2017), lightning and forest fires (Smith 2020; Solomon 2007), and open biomass burning (Biswal et al. 2021; Castellanos et al. 2014).

The COVID-19 outbreak emerged in Wuhan, China, in late 2019 and it was extremely spread around the world. The first case of COVID-19 in Turkey reported on March 11 2020 (Sahin et al. 2021; Sarialioglu Gungor et al. 2021). Then, the information about the COVID-19 was always announced and up-to-dated by the Ministry of Health-Turkey. However, the partial restrictions formally started on April 2020.

Since COVID-19 restrictions made it possible to monitor the anthropogenic variations in air quality,

many researchers investigated the spatiotemporal changes in NO₂ concentration over different areas of the world during the nationwide lockdown of COVID-19 outbreak with remote sensing techniques (Biswal et al. 2021; Dutta et al. 2021; Ghahremanloo et al. 2021; Naqvi et al. 2021; Nichol et al. 2020; Oo et al. 2021; Roşu et al. 2021; Smith 2020).

The aim of this study is to examine the changes in satellite-based tropospheric NO₂ vertical column density (VCD) during the first wave of the lockdown over Mersin Province, Turkey. The tropospheric NO₂ data were derived from The TROPospheric Monitoring Instrument (TROPOMI) onboard the Sentinel 5P satellite, and we used Google Earth Engine (GEE) platform with Java script API capability for the analyses. Since Turkish Government did not apply full lockdown, we considered only lockdown days of 2020 (weekends combined with official and religious holidays presented in Figure 1) in the analysis rather than presenting average monthly images. Then, the lockdown days of 2020 were compared with the corresponding days (considering the same weekend periods) in 2019.

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Cite this study

Ghasempour F, Sekertekin A & Kutoglu H (2021). Effect of first wave COVID-19 outbreak lockdown measures on satellite-based tropospheric NO₂ over Mersin Province, Turkey. 2nd Intercontinental Geoinformation Days (IGD), 16-19, Mersin, Turkey

2. STUDY AREA

Mersin, formerly known as İçel province with having 13 district and 1,868,757 populations (<https://www.nufusu.com/>), is eleventh most populous cities located on the Mediterranean coast of Southern Turkey (Figure 1: in red boundary). Therefore, it includes the Mediterranean climate and the subtropical climate. On the other hand, there is Turkey's largest seaport in this city.

3. DATA USED AND METHOD

The TROPospheric Monitoring Instrument (TROPOMI) onboard Sentinel-5P, the first Copernicus mission, was launched on 13 October 2017 (Butz et al. 2012). The TROPOMI as a passive remote sensing instrument is an advanced multispectral imaging spectrometer with nadir-viewing and wavelengths of Ultraviolet-Visible, Near Infrared and Shortwave Infrared. Besides, it is monitoring several atmospheric gases density in different parts of the electromagnetic spectrum. It works in a cross direction, with ~ 2600 km swath width over the ground surface. The nadir view for NO₂ product is 7x3.5 km² (Veefkind et al. 2012). Many researchers have studied monitoring and retrieval of NO₂ pollutants using Sentinel-5P TROPOMI data (Wang et al. 2021; Zheng et al. 2019).

Fig. 1 illustrates the methodology used in this study in Google Earth Engine (GEE). GEE Java script API was utilized for downloading TROPOMI-based tropospheric NO₂ raster data (COPERNICUS/S5P/OFFL/L3_NO2), preprocessing, visualization, analyzing the NO₂ level changes, and exporting for the first wave periods.

Firstly, we considered the first wave lockdown period around Mersin on specific days in April and May 2020 and also the nearest equivalent days in 2019. The days in 2019 and 2020 do not match since we considered related weekend periods. For example, 13-14 April 2019 is the second weekend in 2019, while 11-12 April 2020 is the corresponding second weekend in 2020.

Here the preprocessing step was the most substantial stage including satellite local pass time(s) filtering and cloudy pixel masking (Fioletov et al. 2020; Ialongo et al. 2020), moreover, to produce one mosaicked image for each day. Eventually, after calculating mean daily images, to create NO₂ maps of the first wave, we generated two mean images for 2019 and 2020.

4. RESULTS

Fig. 2 shows the spatial distribution of mean tropospheric NO₂ vertical column density (VCD) on Mersin at first wave duration for 2020 and corresponding days in 2019. With comparing two maps in 2019 and 2020, we observed a significant reduction, especially in the southeastern part of the interested region, which is the city center of Mersin Province. We also extracted statistical results from mean images during the first wave lockdown in Table 1. As seen in the Table 1, the variation in column density ranged between -0.351*10¹⁵ molec/cm² to 5.238*10¹⁵ molec/cm² with a mean of 1.298*10¹⁵ molec/cm² and between -0.557*10¹⁵ molec/cm² to 3.936*10¹⁵ molec/cm² with a mean of

0.847*10¹⁵ molec/cm² in 2019 and 2020, respectively. The minimum and maximum values were decreased from -0.351*10¹⁵ molec/cm² to -0.557*10¹⁵ molec/cm² and 5.238*10¹⁵ molec/cm² to 3.936*10¹⁵ molec/cm² respectively. In addition, we indicated the change rate (CR) by -0.35 value compared to the according days in 2019. The whisker box plot is displayed using the extracted statistical description of NO₂ VCD for 2019 and 2020 in Fig. 3. As seen in Fig. 3, median, quartile 25% and 75% values are closer to minimum value that these demonstrated a higher value of NO₂ concentration in some of geographical areas. Figure 3 also proves that the height of the boxes indicates the reduction of NO₂ VCD in 2020 lockdown days compared to the same period in the previous year 2019.

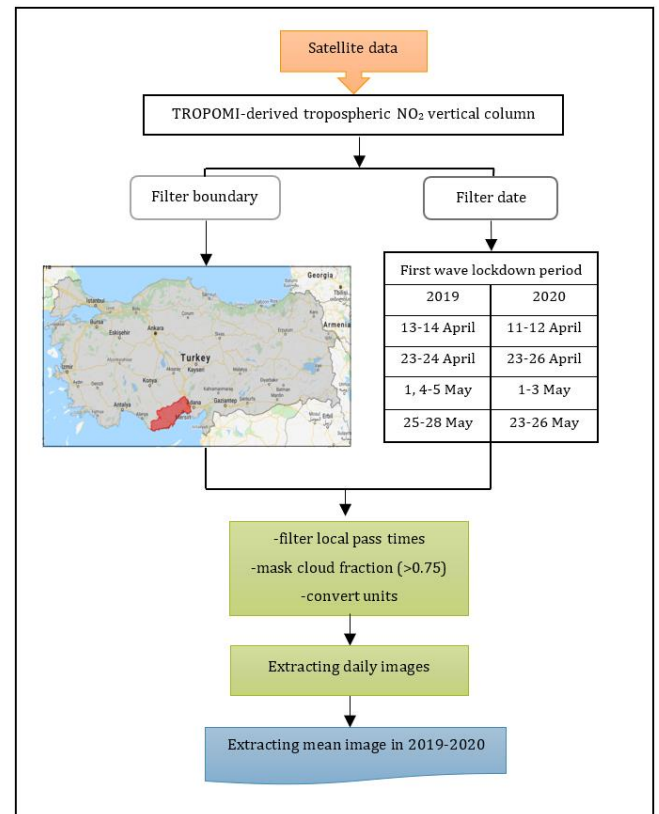


Figure 1. The workflow of the used methodology

Table 1. Descriptive statistics of NO₂ concentration by year. The values should be multiplied by 10¹⁵ except for change rate (CR)

Year	2019	2020
Min	-0.351	-0.557
Q25	0.828	0.578
Median	1.140	0.766
Mean	1.298	0.847
Q75	1.484	1.015
Max	5.238	3.936
STD	0.775	0.486
CR	-0.35	

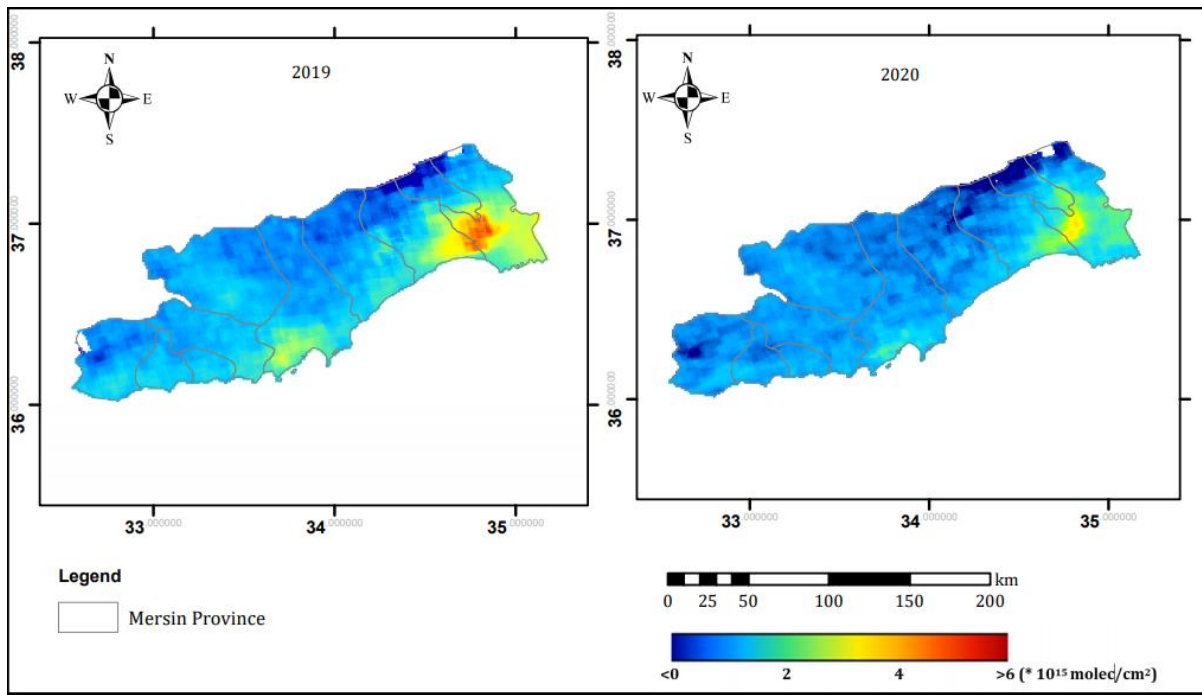


Figure 2. Comparison the average NO₂ VCD in the troposphere first wave lockdown period in 2019 and 2020

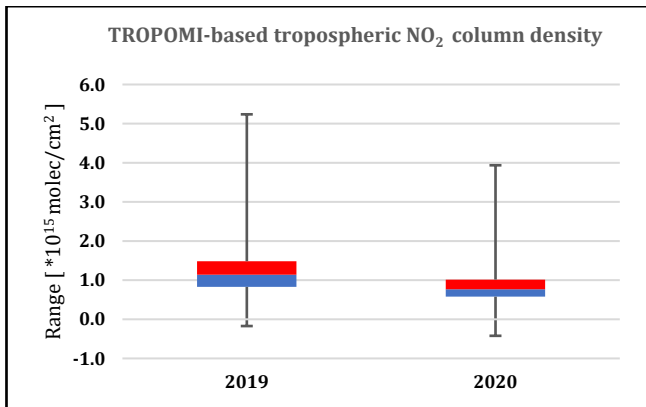


Figure 3. Whisker box plot for mean images derived from the first wave lockdown period in 2020 and previous year 2019

5. DISCUSSION

The derived results represented an important reduction over Mersin with comparing the first wave lockdown on special days of April-May in 2019-2020. However, the possible effect of the meteorological conditions on the air pollutants was ignored in this preliminary study. Besides, due to the fact that having no air quality monitoring station observation in 2019-2020 in the study area, we could not compare TROPOMI-derived NO₂ VCD and NO₂ ground station concentration.

6. CONCLUSION

In this study, we investigated the change of NO₂ VCD concentration as an air pollutant in the first wave lockdown duration over Mersin city in Turkey. We used the NO₂ product derived from TROPOMI instrument onboard Sentinel 5P. Moreover, all operations such as importing the raster data, preprocessing, visualizing, calculating and exporting were conducted using GEE Java script API. Results represented a significant decrease

about 35% over the study area in first wave lockdown period times in 2020 comparing with the according days in 2019. These changes were observed mostly in southeast areas, around the city center, and a part of south of Mersin, close to Silifke district. As a future work, we are going to investigate the relationship between the NO₂ derived from Sentinel 5P images and the meteorological parameters.

ACKNOWLEDGEMENT

The authors wish to thank Google Earth Engine (<https://earthengine.google.com/>), for providing the needed data for this study.

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