

Assessment Of Air Quality Over Pakistan Using Sentinel-5P Observations

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Abstract

Due to rapid increase in urbanization and industrialization, Pakistan is facing severe air quality problems which are causing harmful effects on human health and climate system. Therefore, air pollution has turned out to be an increasingly serious issue in Pakistan. In this study an effort has been made to examine the air quality over five megacities (Lahore, Karachi, Islamabad, Peshawar and Quetta) of Pakistan using Sentinel-5P observations during the period 2018–2021. We used satellite based observational datasets for sulphur dioxide (SO₂), formaldehyde (HCHO) and carbon monoxide (CO) to analyze the air quality over Pakistan. The results showed that mean values of SO₂, HCHO and CO during the study period were 0.000085 mol/m², 0.000112 mol/m² and 0.029455 mol/m² over Pakistan. The maximum concentrations of SO₂, HCHO and CO over Pakistan were found in summer, winter and pre-monsoon seasons, respectively. The highest mean concentrations of SO₂, HCHO and CO were found to be 0.000197 mol/m², 0.000236 mol/m² and 0.040595 mol/m² over Lahore, respectively, while the lowest concentrations of air pollutants were observed over Quetta during the study period 2018–2020. The results showed that concentration of SO₂ increases to about 19.8% over Lahore while HCHO and CO decreases by 2.1% and 1.8% respectively. The concentration of SO₂ increases to about 135.7% and 165.6% over Quetta and Peshawar. Similarly, the concentration of HCHO and CO also increases about 45.3% and 2.1% over Islamabad.

I. Introduction

- Air pollution of Pakistan is included among the most polluted countries on the Earth, and it badly affects the human health.
- Air pollution contributes to the environmental and climate system destruction (Tariq et al., 2016).
- Rapid increase in industrialization, urbanization, crop residue burning, vehicles number and excessive burning of fossil fuels are the major sources of degradation of air quality in Pakistan (ul Haq., 2015).
- Nitrogen dioxide (NO₂), sulfur dioxide (SO₂), carbon monoxide (CO), fine particulate matter (PM_{2.5}), coarse particulate matter (PM₁₀) are main atmospheric pollutants in the atmosphere over Pakistan (Qayyum et al., 2021).
- Trace gases such as sulphur dioxide (SO₂), formaldehyde (HCHO) and carbon monoxide (CO) are found to be highly variable in both time and space in Pakistan.
- Major sources of SO₂, HCHO and CO over Pakistan are transported from volcanic eruptions, and emitted from crop residue burning, industrial emissions, low grade solid and bio-fuels combustions.
- The continuous monitoring of air pollutants in Pakistan is challenging due to the less number of air quality monitoring systems, therefore cost effective remote sensing datasets have been used for the assessment of air quality over Pakistan (Tariq et al., 2018).
- Sentinel-5P TROPOMI provides daily global coverage of SO₂, HCHO and CO with a resolution of 3.5 km × 7 km.

II. Instrumentation

TROPOMI

- TROPOMI onboard the Sentinel-5P satellite operates in the sun-synchronous orbit with an overpass time of 01:30 local solar time.
- Sentinel-5P TROPOMI was launched on 13 October 2017 with the swath width of ~2600 km.
- TROPOMI consists of three spectrometers; one spectrometer contains the shortwave infrared band and the other two contain the ultraviolet-near infrared with two spectral bands (270–500nm and 675–775 nm).
- TROPOMI measures some important atmospheric constituents such as ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, methane, formaldehyde and aerosols.
- TROPOMI provides daily global coverage with a high spatial resolution of 3.5 km × 7 km.
- In this study, we have used the Sentinel-5P TROPOMI OFFLINE L2 products of SO₂, HCHO and CO over Pakistan during the period 2018–2021.

III. Methodology

- Mean annual spatial distribution maps of SO₂, HCHO and CO over Pakistan are made using Sentinel-5P observations from 2018 to 2021.
- Sentinel-5P observations are used for the calculation of mean annual concentration of SO₂, HCHO and CO over Pakistan from 2018 to 2021.
- The datasets of SO₂, HCHO and CO over Pakistan were downloaded from Google Earth engine.
- Sentinel-5P TROPOMI atmospheric measurements are used for the calculation of seasonal concentrations of SO₂, HCHO and CO over Pakistan from 2018 to 2021.
- The relative percentage change in the concentrations of SO₂, HCHO and CO over five megacities (Lahore, Karachi, Islamabad, Peshawar and Quetta) is calculated using the formula mentioned below:

$$\% \text{ relative change} = (\text{Final year} - \text{Initial year}) / \text{Initial year} * 100$$

IV. Results

Mean spatial distribution

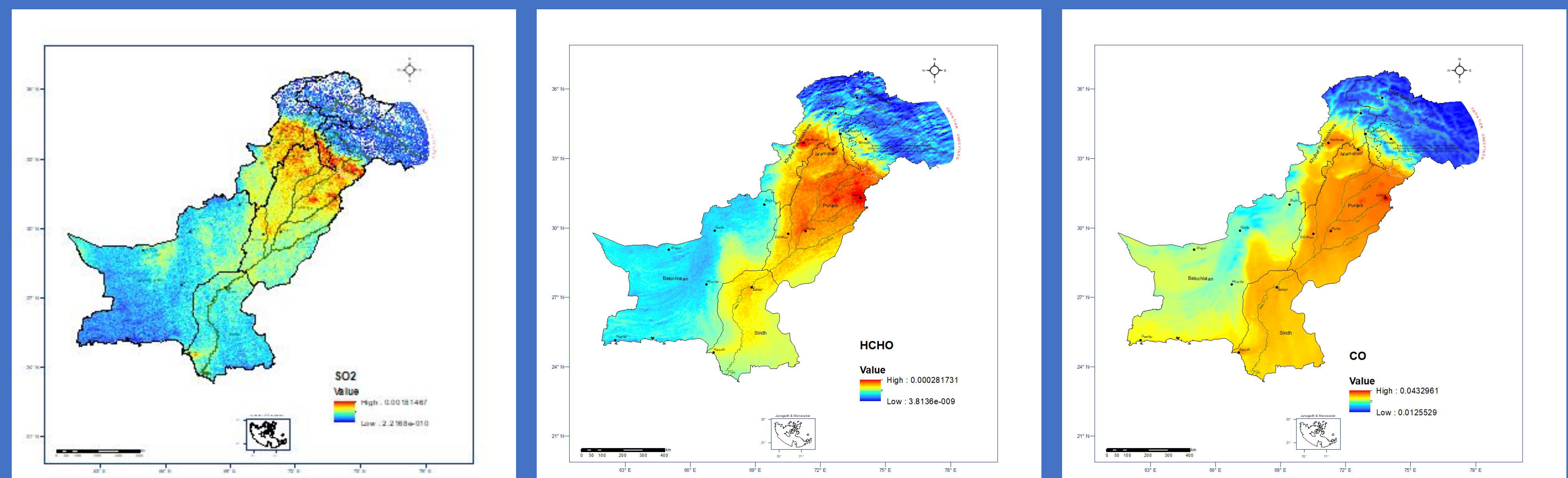


Fig.1: Mean spatial distribution of SO₂, HCHO and CO over Pakistan using TROPOMI observations during the period 2018–2021

Fig.1 shows the high concentration of SO₂, HCHO and CO over northeastern and southeastern regions of Pakistan while low concentration is observed over western areas of Pakistan during the period 2018–2021.

The lowest concentration of trace gases is observed over northern region of Pakistan due to the less population and low industrial activities.

Table 1 shows the descriptive statistics of SO₂, HCHO and CO over Pakistan.

The mean concentration of SO₂, HCHO and CO over Pakistan is found to be 0.000085 mol/m², 0.000112 mol/m² and 0.029455 mol/m² respectively.

The seasonal average concentration of SO₂, HCHO and CO over Pakistan are shown in Table 2.

The highest concentration of SO₂, HCHO and CO is found in DJF, JJA and MAM respectively over Pakistan.

The relative percentage change in the concentrations of SO₂ over megacities is given in Table 3.

The highest % relative change of 135.7% is found over Quetta while the lowest % relative change of -55.9% is observed over Karachi.

The relative percentage change in the concentrations of HCHO over megacities of Pakistan are presented in Table 4.

The highest (lowest) % relative change of 45.3 (-23.9)% is observed over Islamabad (Karachi).

The relative percentage change in the concentrations of CO over megacities of Pakistan are shown in Table 5.

The highest % relative change of 3.56% is found over Quetta while the lowest % relative change of -1.85% is observed over Lahore.

Table 1. Descriptive statistics of SO₂, HCHO and CO over Pakistan during the period 2018–2021

Pakistan	Mean	Max	Min	STD
SO ₂	0.000085	0.001815	-0.000664	0.000057
HCHO	0.000112	0.000279	-0.000018	0.000051
CO	0.029455	0.043296	0.012966	0.007026

Table 2. Seasonal average concentrations of SO₂, HCHO and CO over Pakistan during the period 2018–2021

Parameters	MAM	JJA	SON	DJF
SO ₂	0.00008	0.000029	0.000097	0.000224
HCHO	0.000111	0.000139	0.000122	0.000107
CO	0.030224	0.028861	0.028531	0.030141

Table 3. % relative change in the concentrations of SO₂ over megacities between January 2019 and 2020.

SO ₂	January 19	January 20	% Relative change
Quetta	0.000126	0.000297	135.7
Islamabad	0.000463	0.000481	3.88
Peshawar	0.000321	0.000853	165.6
Lahore	0.000398	0.000477	19.8
Karachi	0.00022	0.000097	-55.9

Table 4. % relative change in concentrations of HCHO over megacities between January 2019 and 2020

HCHO	January 19	January 20	% Relative change
Quetta	0.000056	0.000053	-5.3
Islamabad	0.000119	0.000173	45.3
Peshawar	0.000174	0.000183	5.17
Lahore	0.000185	0.000181	-2.16
Karachi	0.000138	0.000105	-23.9

Table 5. % relative change in concentrations of CO over megacities between January 2019 and 2020

CO	January 19	January 20	% Relative change
Quetta	0.024635	0.025514	3.56
Islamabad	0.037036	0.037848	2.19
Peshawar	0.038807	0.038563	-0.62
Lahore	0.041181	0.040419	-1.85
Karachi	0.038254	0.037721	-1.39

V. Conclusion

This study shows the assessment of air quality over Pakistan using the datasets of some selected air pollutants obtained from Sentinel-5P during the period 2018–2021. The mean annual and seasonal concentrations of SO₂, HCHO and CO were examined over Pakistan. Higher concentration of SO₂, HCHO and CO were observed over Pakistan which show deterioration of air quality. All the pollutants show strong seasonality over Pakistan. The assessment of air quality over megacities (Lahore, Karachi, Islamabad, Peshawar and Quetta) were also examined from 2018 to 2021. The % relative change in the concentrations of SO₂, HCHO and CO were also calculated over megacities. The highest % relative change in the concentration of SO₂ is observed over Peshawar in January 2020 as compared to the same month of the previous year.

VI. References

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