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Study UVI, ozone Column and AOD and Investigate the Change in Its values Between a Dust Storm Day and a Calm Day Over Baghdad in 2021

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Abstract:

This study examines the daily variations and interactions of aerosol optical depth (AOD), total vertical ozone (O_3), and UV index (UVI) in 2021 to assess their impact on surface UV radiation. The findings indicate that aerosol loading has a major impact on UV transmission, and that greater AOD values diminish surface UVI by increasing scattering and absorption. However, when solar radiation is significant, aerosol absorption may indirectly contribute to ozone generation by boosting lower troposphere temperature. Total vertical ozone continues to serve an important protective role by reducing UV light, and seasonal ozone depletion is regularly related with increased UVI levels. Spring was characterized by moderate to high UVI, as well as increases in AOD and O_3, indicating enhanced photochemical activity. In contrast, summer has reduced aerosol and ozone loads, resulting in generally steady ultraviolet (UV) values that are mostly controlled by humidity and cloud cover. Winter, on the other hand, is distinguished by a consistent reduction in UV light, little photochemistry, and decreased aerosol concentrations. UV radiation has been demonstrated to correlate with both aerosol optical characteristics and ozone column height, indicating its value as an indicator for monitoring air quality, detecting climatic feedback mechanisms, and calculating the danger of human UV exposure. During a dust storm, the number of aerosols in the atmosphere increases dramatically. These particles in the air help to absorb and disperse sunlight. As a result, the AOD increases considerably during a dust storm.

Keywords: *Aerosol Optical Depth (AOD); Total Column Ozone (O_3); Ultraviolet Index (UVI); Dust Aerosols; Air Quality Assessment*

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1. Introduction

In terms of the climate, air quality, and health of the planet, atmospheric composition and solar UV radiation are closely related. The Aerosol Optical Depth (AOD), O_3 (particularly total column or near-surface), and the Ultraviolet Index (UVI) at the Earth's surface are the three main interconnected parameters that are the focus of this investigation. The dimensionless measurement of the combined extinction (scattering & absorption) of solar radiation by aerosol particles in a vertical atmospheric column (from the surface to the top of the atmosphere) at a specific wavelength is known as Aerosol Optical Depth (AOD). It is frequently used to measure atmospheric turbidity and particulate matter loading, and it shows how much aerosols block direct solar irradiance from reaching the surface (via Beer-Lambert law) [1]. Ozone column (O_3) in the troposphere and stratosphere. By absorbing incoming solar UV-B radiation, ozone in the stratosphere reduces UV irradiance at the surface and functions as a UV shield. Ozone is a secondary pollutant in the troposphere that is created by photochemical reactions between sunlight, NO_x, and VOCs. It functions as an oxidant that influences aerosol interactions, photochemistry, and air quality. Therefore, near-surface ozone, also known as total column ozone (TCO), interacts with aerosol processes and affects surface UV radiation [2]. UVI stands for ultraviolet index. The amount of erythemal weighted UV radiation that reaches the Earth's surface, primarily UV-B but also UV-A weighted by biological action spectrum, is measured by the UVI, a standardized index. cloud cover, surface albedo, aerosol loading, solar zenith angle (SZA), total column ozone (which blocks UV rays), and optical properties (which absorb and scatter UV). For example, recent studies show that changes in clouds, ozone, and aerosol content have measurable effects on UVI trends [3]. Radiative and photochemical processes link these three variables both chemically and physically:

By physically attenuating incoming solar UV radiation through absorption and scattering, aerosols (reflected in AOD) tend to lower UVI by lowering surface UV-dose. Simultaneously, absorbing aerosols (such as dust and black carbon) can alter stability and mixing, heat the atmospheric column, and indirectly affect the troposphere's ability to form ozone. For instance, Kim et al. (2012) discovered that erythemal UV increased by approximately 1.18 percent for every 1% decrease in total ozone, and that AOD and solar zenith angle modulated this relationship [4].

Total column ozone (O_3) directly affects UV-B rays that reach the surface: higher UVI and higher photolysis rates of ozone precursors result from lower ozone, which may raise tropospheric ozone. For instance, Kazadzis et al. (2022) demonstrate that seasonal ozone variations cause UVI at mid-latitudes to change by almost a factor of two at fixed SZA [5].

In some situations, a higher aerosol optical depth (AOD) can inhibit the production of ozone by lowering UV flux and, consequently, photolysis rates (particularly when precursor supply is limited). On the other hand, depending on the circumstances, some scattering aerosols may enhance diffuse radiation and thereby intensify photochemistry. For example, a study conducted in the Beijing area discovered that UV radiation was extremely sensitive to AOD changes, ranging from 0.2 to 1.0, with attenuation up to 30 % [6].

Column ozone shielding, aerosol attenuation/scattering, solar geometry, clouds, and surface reflectivity are all competing effects that contribute to the final UVI seen at the surface. According to the UNEP assessment (2023), clouds and aerosol changes were the primary drivers of recent changes in surface UV radiation, with ozone often having a minor impact [7].

The integrated study of AOD, O_3, and UVI in regional contexts is motivated by this conceptual framework, especially in arid and semi-arid zones where solar radiation is high and aerosol loading may predominate.

In the 2015 paper "UV Radiation Sensitivity to Total Ozone Variations under Different Celestial Conditions: Results from Granada, Spain," researchers looked at how changes in the total ozone column influence ultraviolet (UVER) radiation under various astronomical settings. The study concluded that the relative amplification factor (RAF) increased from around 1.1 to nearly 1.4 as cloud cover increased, demonstrating that ozone had a stronger effect on UV radiation under cloudy skies.[8] A complete study titled "Evaluation of UV Aerosol Retrieval from Ozone LiDAR," released in 2020, created an algorithm for extracting aerosol data at UV wavelengths using ozone lidar. Because aerosols and ozone interact with UV retrieval, the study found an AOD retrieval error of around 299 nm rather than 532 nm [9]. An 11-year period (2010–2020) in Rome was examined in a 2022 study titled "Aerosol optical characteristics in the urban area of Rome, Italy, and their impact on the UV index." to look into how UVI is affected by AOD and SSA (single scattering exposure). Depending on the particle type and the sun's angle, the study discovered that a significant drop in UVI (which could surpass 50%) was linked to either increased AOD or decreased SSA (increased absorption) [10].

A 2022 study called "Relationship between ozone and biologically relevant UV at 4 NDACC sites" used statistical analysis to eliminate the effects of aerosols and clouds before concentrating on the connection between ozone and UV radiation that is visible in the clear sky. According to the study, UV radiation changed significantly with seasonal changes in the ozone column, especially at mid-latitudes [11].

"Impact of aerosol optics on vertical distribution of ozone in autumn over Yangtze River Delta" is the title of a published study in 2023. Aerosols containing adsorbent components reduce photolysis and thus influence the vertical ozone distribution in autumn, according to an analysis of the effects of aerosol properties (adsorption/scattering) on ozone distribution in the atmospheric column using the WRF-Chem model [12].

Total ozone column and aerosol absorption coefficient (UVAI) were associated with natural and man-made sources in South Asia in a 2023 study entitled "Identifying the natural and anthropogenic drivers of absorbing aerosols using OMI data and HYSPLIT model over South Asia." In certain instances, the study discovered a link between higher UV AI and lower total ozone, indicating that absorbing particles and column ozone interact to modulate UV radiation [13].

"Stratospheric ozone, UV radiation, and climate interactions," a thorough evaluation released in 2023, examined the effects of aerosols, surface reflectors, solar radiation, and stratospheric ozone on surface UV radiation. It came to the conclusion that, more often than not, changes in clouds and aerosols have been the main causes of UV change at low and mid-latitudes over the past few decades [14].

UV Aerosol Index data from the OMI satellite in the Arctic region were examined in a 2023 study titled "Ozone Monitoring Instrument (OMI) UV aerosol index data analysis over the Arctic region for future data assimilation and climate forcing applications." It discovered that during the summer of 2014–2020, there was an increase in UV-absorbing aerosol events in northern Russia and Canada, and that incidental biases necessitated special correction for the quality of the data. This emphasizes how crucial aerosols are for regulating ozone and UV radiation in polar regions [15].

Data and research domain:

Figure (1) displays the daily values of aerosol optical depth (AOD), ultraviolet index (UVI), and depth of column ozone over the city of Baghdad (44.4,33.3) based on data from the ECMWF and MODIS Terra – MOD08_D3 – Aerosol Optical Depth at 550 nm Daily Level-3, Grid: 1° × 1°for the year 2021.

Figure (1): location of Baghdad in Iraq

2. Methodology:

The daily observational data gathered during 2021 served as the basis for this investigation. The MODIS (Moderate Resolution Imaging Spectroradiometer) platform aboard the Terra and Aqua satellites provided the Aerosol Optical Depth (AOD) at 550 nm. OMI (Ozone Monitoring Instrument) Level-3 global gridded products were used to extract total column ozone (O_3). The Tropospheric Emission Monitoring Internet Service (TEMIS) database provided the daily Ultraviolet Index (UVI) data. To guarantee spatial consistency among the three parameters, values corresponding to the study region were extracted at the center grid cell after all datasets had been regraded to a uniform spatial resolution before analysis.

Result Analyses and discussions:

The daily relationship between the aerosols optical depth and the ultraviolet index was plotted for each month of the year 2021, and the results appeared as shown in Figure (2). Temporary AOD peaks in January signify days with smog or dust, which may lower UVI at night.

Figure (2): relationship between the aerosol optical depth and the ultraviolet index

There is a weak inverse relationship between the two: the higher the AOD, the slightly lower the UVI. February: There is a definite inverse relationship between high AOD during specific periods and a decrease in UVI during the same periods, which is indicative of an increase in atmospheric particles (dust or pollution). March: The effect of particulate matter in reducing ultraviolet radiation is demonstrated by the apparent decrease in UVI that occurs with every increase in AOD.

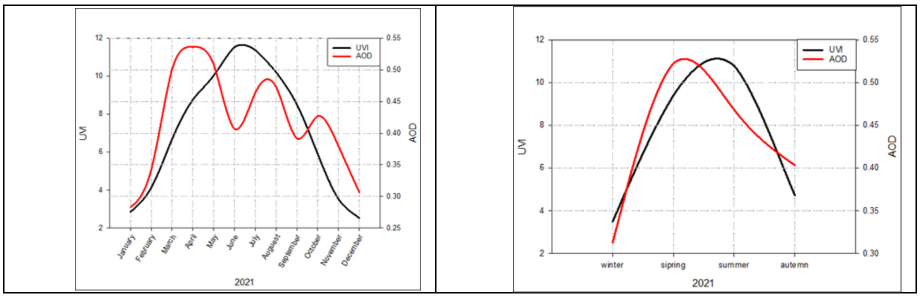
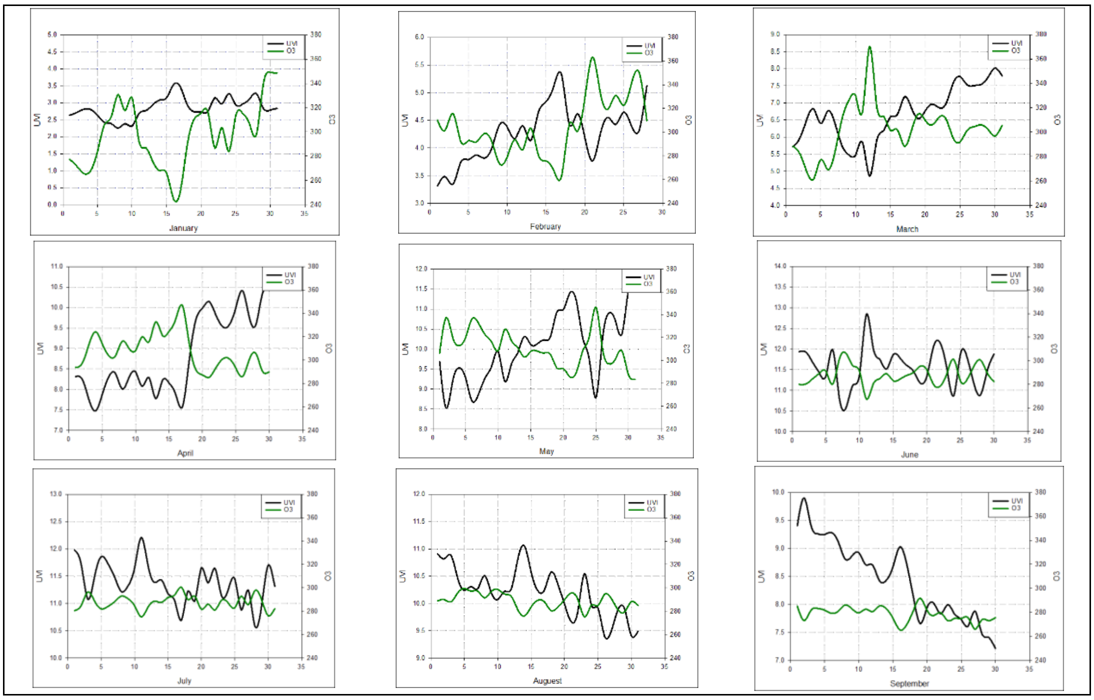


Figure (3): Monthly and seasonal relationship between the aerosol optical depth and the ultraviolet index

There is a strong inverse relationship. April: The inverse relationship lessens and the values approach equality as the weather stabilizes and the sky clears. May: The impact of dust is minimal because the skies are primarily clear. The relationship between UVI and AOD is weak or nonexistent, and UVI is extremely high. June: Summer: Low concentration of aerosols, high radiation, and clear skies. The two variables hardly have any discernible relationship. July: The absence of clouds and particulate matter keeps the UV index high, but the AOD is low. The relationship is neutral and nearly constant. August: The impact of AOD is minimal in late summer when there are still clear skies. There is hardly any relationship at all. September: The relationship is weak and negligible because the solar angle, not a change in AOD, is what causes the UVI to decrease. October: The inverse relationship is further supported by the start of light dust activity. November: The cold and lack of wind cause particulate matter to rise, which lowers UV radiation. a substantial inverse correlation. December: UVI is decreased by cold weather and frequently cloudy or dusty conditions. a somewhat inverse correlation. We draw the conclusion that, particularly in months with a high frequency of storms or dust, the ultraviolet index (UVI) falls as the aerosol optical depth (AOD) rises because the particles block sunlight. As seen in Figure (3), monthly average values were computed and plotted as monthly and seasonal relationships.

The daily relationship between the ultraviolet index and the ozone column was plotted for each month of the year 2021, and the results appeared as shown in Figure (4).



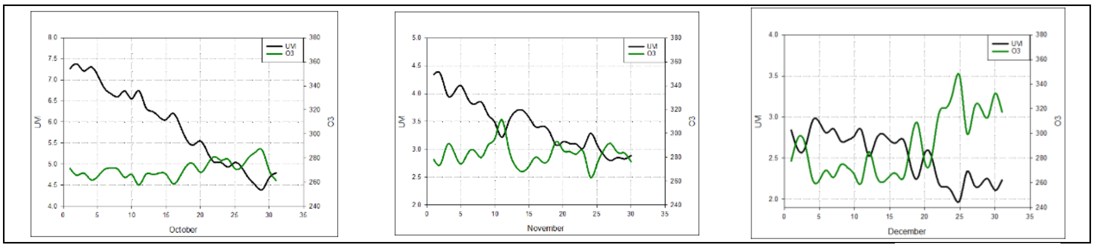


Figure (4): relationship between the ultraviolet index and the ozone column

A clear temporal variability in the behavior of the Ultraviolet Index (UVI) and the Aerosol Optical Depth (AOD) is revealed by the monthly and seasonal analysis of data for 2021. This indicates the reciprocal influence of atmospheric aerosol loading and solar radiative activity. Wintertime saw the lowest UVI values, mostly as a result of higher humidity, more clouds, and a smaller solar elevation angle. On the other hand, it peaked in the summer, when the intensity of solar radiation and the transparency of the atmosphere were at their highest.

On the other hand, the AOD displayed the opposite trend. Its values rose sharply in the spring in tandem with the seasonal dust outbreaks and increased concentration of atmospheric aerosols, then gradually decreased during the summer as the atmosphere stabilized and the skies cleared. In the fall, it rose once more as a result of increased humidity and sporadic dust resuspension.

According to a comparison of the two parameters, UVI and AOD have a usually inverse relationship: higher aerosol concentrations diminish surface UV radiation due to reduced atmospheric absorption and scattering mechanisms. However, in the spring, when both indices rose simultaneously due to increased solar radiation and dust storm activity, a transient direct association was observed. To summarize, the yearly difference between UVI and AOD demonstrates how meteorological and climatic variables dynamically influence how much UV radiation from the sun reaches the surface. As a result, AOD can be regarded as an important metric in explaining the temporal and spatial variability of UV exposure, as well as the climatic and environmental consequences that accompany it.

This graph shows daily fluctuations in UVI and ozone column concentrations in 2021. A consistent seasonal tendency is observed: UVI values steadily rise from winter to summer before falling at the end of the year. In contrast, O_3 concentrations decline steadily in warmer months and increase in colder months. This inverse association shows that ozone plays a vital role in reducing UV radiation, because higher ozone levels lead to stronger absorption of UV-B wavelengths and thus a lower UVI index at the surface.

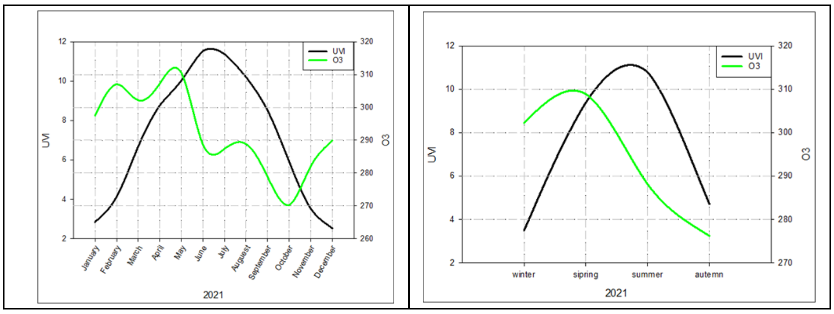


Figure (5): monthly and seasonal relationship between the ultraviolet index and the ozone column

Daily variations in the UVI index are more pronounced than those in ozone due to the influence of short-term weather factors such as cloud cover, humidity, and the sun's altitude.

Monthly average values were calculating and plotting as monthly and seasonal relationships as shown in Figure (5).

The monthly mean relationship between UVI and O_3 for 2021 is displayed by Monthly Correlation. In June and July, when solar radiation peaks around the summer solstice, the highest UVI values are recorded. On the other hand, the concentration of ozone peaks in the spring (March–April) and then progressively declines as summer approaches. The two curves clearly show an inverse relationship: UVI increases as ozone concentrations fall and vice versa. The ozone layer's absorption properties, which specifically absorb UV-B rays, are responsible for this pattern. The temporal variability seen in both parameters is also influenced by seasonal dynamics of atmospheric circulation and stratosphere–troposphere exchange.

The seasonal averages of UVI and O_3 for 2021 are also summarized in figure (5). Because of lower solar altitude and weaker insolation, UVI values are at their lowest during the winter, while O_3 concentrations are relatively high. As sun energy increases in the spring, UVI gradually rises, whereas O_3 falls slightly. Summer is characterized by low O_3 levels and high UVI levels due to strong sun irradiation. Autumn: Both metrics begin to revert as UVI declines and ozone concentrations largely recover.

This seasonal cycle highlights the interplay between solar radiation intensity and ozone column thickness in controlling surface UV exposure. For the entire year 2021, the analysis clearly demonstrates an inverse relationship between UVI and O_3. Since summertime has the highest UVI and the lowest ozone concentrations, there is a greater chance of UV exposure due to increased ultraviolet penetration to the surface. These results are in line with earlier international research that connected variations in surface UV radiation to stratospheric ozone variability. The observed patterns verify that the study region's UV radiation levels are primarily modulated by the seasonal evolution of ozone.

The daily relationship between the aerosol optical depth and the ozone column was plotted for each month of the year 2021, and the results appeared as shown in Figure (6).

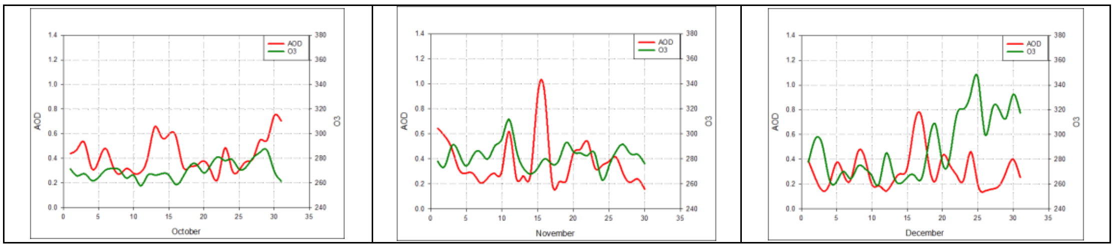


Figure (6): relationship between the Aerosol Optical Depth and the ozone column

AOD values gradually increased starting in January and peaked sharply in March and April, then declined in the summer and then increased again in October and November, according to the monthly plots. Increased dust activity and frequent dust storms, which are usually caused by stronger surface winds and dry conditions over arid and semi-arid regions, are responsible for the springtime enhancement of AOD. Wet scavenging processes and increased humidity brought on by convective precipitation, which efficiently remove aerosols from the atmosphere, are probably the causes of the ensuing summer decline.

Ozone (O_3) concentrations, on the other hand, show a somewhat opposite pattern, peaking in the spring (March–April), declining noticeably in the summer, and then rising moderately in late autumn. Lower wintertime radiation and stable atmospheric conditions inhibit photochemical production, whereas increased solar radiation and photochemical reactions in the spring encourage the formation of tropospheric ozone.

As seen in Figure (7), monthly average values were computed and plotted as monthly and seasonal relationships.

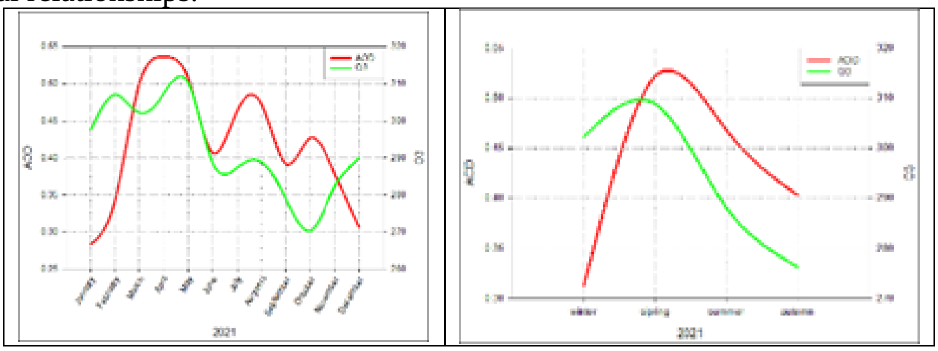


Figure (7): monthly and seasonal relationship between the Aerosol Optical Depth and the ozone column

Both AOD and O_3 reach their maximum values in the spring, with AOD approaching 0.5 and ozone reaching about 310 Dobson Units, according to the seasonal composite (third graph). This concurrent improvement raises the possibility of a relationship between increased aerosol loading and heightened photochemical activity, which leads to a rise in ozone production. On the other hand, as a result of decreased solar radiation and weakened photochemical processes during the colder months, both parameters gradually decrease during the summer and fall before reaching their lowest levels in the winter. AOD and O_3 have a nonlinear and partially asynchronous relationship, according to the analysis. Although they peak together in the spring, there are differences in other seasons, suggesting that the relationship between aerosols and ozone is highly dependent on the makeup of the aerosols and the radiative effects of various particle types. While scattering aerosols, like sulfates, can lower surface photolysis rates and thereby suppress ozone production, absorbing aerosols, like black carbon, may increasing in atmospheric heating and promote ozone formation.

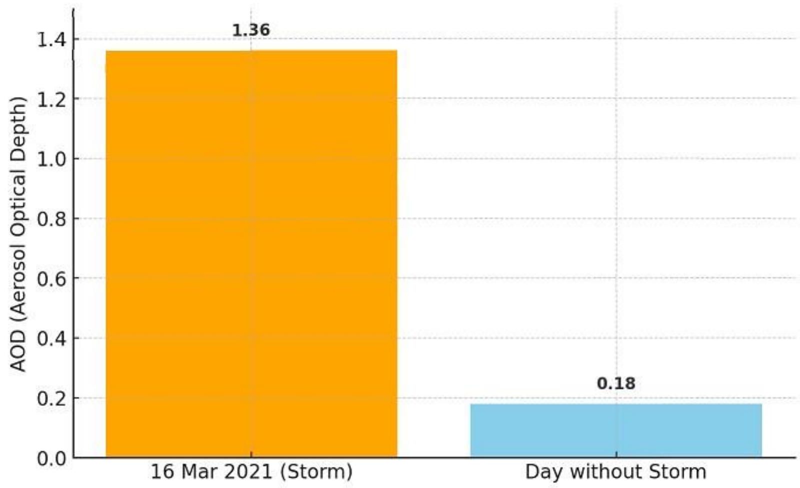


Figure (8): Comparison of AOD on a Dust Storm Day vs normal day in Baghdad

In the 2021 data, (AOD) and (O_3) show significant seasonal tendencies, with the lowest values recorded in winter under more stable and colder conditions, and the greatest values recorded in spring due to the combined impacts of dust emissions, strong solar radiation, and improved photochemistry. These findings illustrate the complex atmospheric interactions between aerosols and ozone, emphasizing their importance in regulating regional air quality and the radiative effects of climate.

We selected the dust storm that struck Baghdad on 16/3/2021 and contrasted its AOD values with those of a clear day in order to investigate the impact of dust storms on AOD values. Figure (8) displays the findings.

The quantity of dust aerosols, or suspended solid particles, in the atmosphere rises dramatically during a dust storm .In the air column, these particles enhance solar radiation absorption and scattering. The two main factors taken into account when calculating are as follows :Aerosol optical depth, or AOD, is the optical depth of the air column's constituent particles. As a result, AOD rises sharply during a dust storm, creating peaks. As the winds calm down and the particles settle, it starts to progressively diminish right after the storm.

Conclusion:

The study results showed that UV are controlled by radiative and photochemical interactions between aerosols, ozone and solar intensity. High AOD values suppress UV radiation by enhancing scattering and absorption, while total column ozone still plays a protective role by attenuation UV-B radiation. Seasonal variations show that despite partial UV attenuation due to dust, the strongest radiative- photochemical coupled occurs in spring, when increased solar irradiance promotes ozone formation. Conversely Due to lower aerosols loads, reduced photochemical efficiency, and increasing in cloud associated modulation, summer and winter are characterized by weaker interactions. In all respects, UV radiation is considered an integrated atmospheric response variable that reflects the optical properties of aerosols as well as the depth of the ozone column. Therefore, it can be a useful diagnostic indicator for assessing short-term atmospheric radiation conditions. The results highlight the need to incorporate ultraviolet radiation (UV) into assessments of aerosol-ozone interactions and the importance of using high-frequency (daily) datasets in regions with marked seasonal variations. Future research should utilize UV spectral distribution and radiation transmission modeling to determine the relative contributions of aerosol types and ozone vertical distribution to UV fluctuations. During a dust storm the number of aerosols in the atmosphere increasing significantly. These partials in the air help absorb and scatter sunlight. As a result, the AOD rises dramatically during a dust storm.

References:

1. Holben, B. N., Tanré, D., Smirnov, A., Eck, T. F., Slutsker, I., Abuhassan, N., ... & Zibordi, G. (2001). An emerging ground‐based aerosol climatology: Aerosol optical depth from AERONET. *Journal of Geophysical Research: Atmospheres*, *106*(D11), 12067-12097.
2. Huneeus, N., Chevallier, F., & Boucher, O. (2012). Estimating aerosol emissions by assimilating observed aerosol optical depth in a global aerosol model. *Atmospheric Chemistry and Physics*, *12*(10), 4585-4606.
3. Bernhard, G. H., Bais, A. F., Aucamp, P. J., Klekociuk, A. R., Liley, J. B., & McKenzie, R. L. (2023). Stratospheric ozone, UV radiation, and climate interactions. *Photochemical & Photobiological Sciences*, *22*(5), 937-989.
4. Kim, J., Cho, H. K., Mok, J., Yoo, H. D., & Cho, N. (2013). Effects of ozone and aerosol on surface UV radiation variability. *Journal of Photochemistry and Photobiology B: Biology*, *119*, 46-51.
5. McKenzie, R., Liley, B., Kotkamp, M., Geddes, A., Querel, R., Stierle, S., ... & Madronich, S. (2022). Relationship between ozone and biologically relevant UV at 4 NDACC sites. *Photochemical & Photobiological Sciences*, *21*(12), 2095-2114.
6. Zhao, S., Xin, H., Wu, S., Sun, Y., & Hu, B. (2024). Attenuation of ultraviolet radiation by aerosols and clouds in Beijing area in 2005–2020. *Atmosphere*, *15*(3), 311.
7. Bernhard, G. H., Bais, A. F., Aucamp, P. J., Klekociuk, A. R., Liley, J. B., & McKenzie, R. L. (2023). Stratospheric ozone, UV radiation, and climate interactions. *Photochemical & Photobiological Sciences*, *22*(5), 937-989.
8. Antón, M., Cazorla, A., Mateos, D., Costa, M. J., Olmo, F. J., & Alados‐Arboledas, L. (2016). Sensitivity of UV erythemal radiation to total ozone changes under different sky conditions: Results for Granada, Spain. *Photochemistry and Photobiology*, *92*(1), 215-219.
9. Kuang, S., Wang, B., Newchurch, M. J., Tucker, P., Eloranta, E. W., Garcia, J. P., ... & Natraj, V. (2020). Evaluation of UV aerosol retrievals from an ozone lidar. *Atmospheric Measurement Techniques Discussions*, *2020*, 1-20.
10. Campanelli, M., Siani, A. M., di Sarra, A., Iannarelli, A. M., Sanò, P., Diémoz, H., ... & Dietrich, S. (2019). Aerosol optical characteristics in the urban area of Rome, Italy, and their impact on the UV index. *Atmospheric Measurement Techniques Discussions*, *2019*, 1-23.
11. McKenzie, R., Liley, B., Kotkamp, M., Geddes, A., Querel, R., Stierle, S., ... & Madronich, S. (2022). Relationship between ozone and biologically relevant UV at 4 NDACC sites. *Photochemical & Photobiological Sciences*, *21*(12), 2095-2114.
12. Yan, S., Zhu, B., Shi, S., Lu, W., Gao, J., Kang, H., & Liu, D. (2023). Impact of aerosol optics on vertical distribution of ozone in autumn over Yangtze River Delta. *Atmospheric Chemistry and Physics*, *23*(9), 5177-5190.
13. Nawaz, H., Tariq, S., Haq, Z. U., & Mehmood, U. (2023). Identifying the natural and anthropogenic drivers of absorbing aerosols using OMI data and HYSPLIT model over South Asia. *Air Quality, Atmosphere & Health*, *16*(12), 2553-2577.
14. Bernhard, G. H., Bais, A. F., Aucamp, P. J., Klekociuk, A. R., Liley, J. B., & McKenzie, R. L. (2023). Stratospheric ozone, UV radiation, and climate interactions. *Photochemical & Photobiological Sciences*, *22*(5), 937-989.
15. Sorenson, B. T., Zhang, J., Reid, J. S., Xian, P., & Jaker, S. L. (2023). Ozone Monitoring Instrument (OMI) UV aerosol index data analysis over the Arctic region for future data assimilation and climate forcing applications. *Atmospheric Chemistry and Physics*, *23*(12), 7161-7175.