Nat. Volatiles & Essent. Oils, 2022; 9(2): 772-783

Aerosol Optical Depth And Angstrom Exponent Observation Over Syria Using Modis/Aqua Satellite Data During 2010-2020

Teysir Alzamil[1] and Fatema Battour[2]

[1]Associate Professor, Aleppo University in Liberated Areas, Physics Department, Azaz, Syria.

[2]Lecture, Aleppo University in Liberated Areas, Physics Department, Azaz, Syria.

ABSTRACT

Pollutants that are emitted to the atmosphere cause wide climatic changes which have greatly affected the aspects life on Earth. Aerosols are one of the most important of these pollutants, and emitted into the atmosphere from natural and anthropogenic sources. In this research, we studied the properties of aerosols AOD (Aerosol Optical Depth), AE (Angstrom Exponent) over Syria during 2010 - 2020 using MODIS/Aqua satellite, the results of this study showed that AE and AOD changes significantly during the study period. The results of the annual changes of AOD over Syria showed that the large values were over Al Dear, while the small values were over Aleppo, and the minimum value was 0.19 ± 0.006 in 2014, While the average monthly changes of AOD showed that the maximum values were 0.44 ± 0.091 in May and 0.395 ± 0.07 in September. The results of the seasonly changes of AOD over Syria also showed that the values of AOD were low in winter, then rise in spring and summer, after that decrease again during the autumn. While the results for the average monthly changes of AE over Syria during 2010 -2020 showed that the maximum values of AE were 0.89 ± 0.07, 0.839 ± 0.07 during January and December respecively, the lowest values 0.42 ± 0.1 was in September. As for the seasonal changes of AE, it was shown that the small values of AE were in summer, while the large values were during winter. Classification of aerosols over Syria during 2010 – 2020 showed that the aerosol over Syria is largely composed of maritime type.

Key words: Aerosol, climate, AOD, AE, MODIS, Syria.

1- INTRODUCTION

Air pollutants which emitted into the atmosphere from various sources such as industrial processes, burning fossil fuels and transportation, travel thousands of kilometers to reach the atmosphere and affect on climate [1]. The great climatic changes resulting from atmospheric pollution are greatly affect on the environment and economy. There are many types of pollutants which emitted to the atmosphere, such as greenhouse gases and aerosols [2]. Aerosols are liquid and solid particles suspended in the atmosphere and greatly affect the radiative balance [3]. Small particles of sand and dust are a form of aerosol that travels from the earth's surface through the wind [4]. Aerosols are emitted into the atmosphere either from natural sources such as particles resulting from volcanic eruptions, sea spray, desert dust, cultivated surfaces and large fires, or from industrial sources such as combustion from automobile engines, solid fuels (coal), evaporation of lakes and industrial processes [5]. The size of the aerosol varies depending on the sources that emit it, aerosol size ranging from 10^{-3} to 10^{-2} µm. While in terms of shape, aerosols are classified into the following types: isomeric particles, platelets and fibres [6]. Aerosols affect climate changes through many processes as follows: firstly scattering and absorbing solar rays. Secondly scattering and solar emission, and thirdly affecting on process of cloud formation [7]. Whereas numerous studies using satellite data have proven that aerosols significantly affect cloud formation [8]. Because of the significant temporal and spatial changes of aerosols in the atmosphere, its negative symptoms have begun to appear on human health [9]. The dust storm that reached the Middle East in September 2015, whose impact extended to Syria and northern Iraq, caused great health damage [10]. The aerosols caused damage to eye and inflammation in the lungs, and many residents in Syria were transferred to hospitals during 6-9 September 2015 due to the dust storm [11]. Given the great importance of aerosol changes in the atmosphere, many researches have used remote sensing technology such as MODIS (Moderate Resolution Imaging Spectroradiometer) to study the distribution of aerosols [12]. In this research, we have studied two properties of aerosols AOD (Aerosol optical depth) and AE (Angstrom exponent) over Syria during 2010 - 2020 using MODIS/ Aqua satellite data. MODIS operates on board Aqua satellite, which was launched in 2002, and was designed to support weather and climate research [13][14]. The MODIS instrument is located on board the two Aqua and Terra satellites which rotate in polar orbit at 705 Km altitude [15]. MODIS has 36 frequency channels that sense visible and infrared radiation within wavelengths 0.4 -14.4 µm [16]. MODIS has a high spatial resolution (1 km or less), swath wide 2,600 km, and it provides daily global coverage of aerosols [17][18]. Data can be obtained from the MODIS Aqua instrument through the NASA website https:// giovanni.gsfc.nasa.gov/ giovanni/ [19].

Figure (1) and (2) which obtained from Giovanni, show the changes of the AOD and AE over the world in December 2020

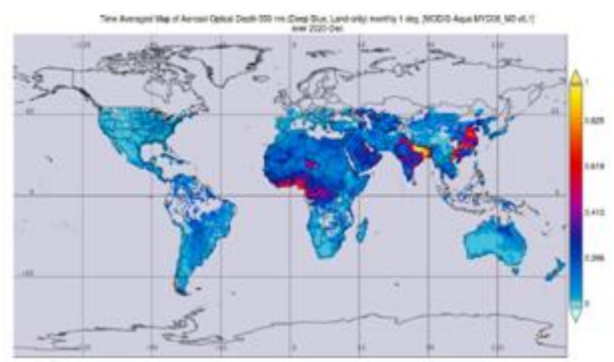


Figure (1) AOD over the world in December 2020

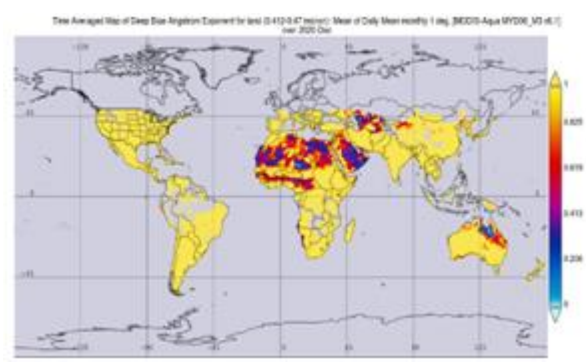


Figure (2) AE over the world in December 2020

2 - DATA AND METHODOLOGY

Study Area:

Syria is located between latitudes (32-37) north and longitudes (35-42) east in the southwest of the continent of Asia on the eastern coast of the Mediterranean Sea, bordered by Turkey to the north, to the south by Jordan, to the southwest by Palestine, to the east by Iraq, to the west by Lebanon and the Mediterranean Sea [20]. Figure (3) shows a map of Syria where this study was conducted [21].

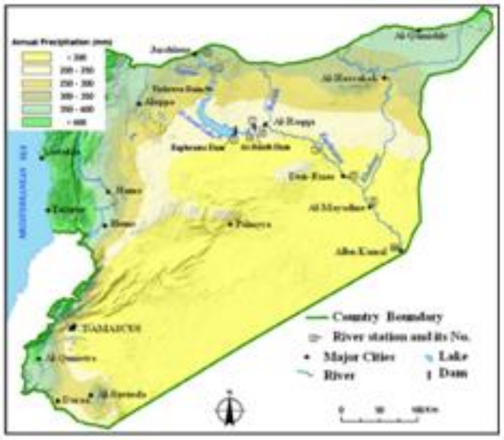


Figure (3) Map of Syria

Aerosol Optical Properties (AOD, AE):

AOD is an important parameter in the atmosphere and is mainly associated with aerosols and it is less dimension. This parameter is a measure of scattering of the radiation as a result of its interaction with aerosols in the atmosphere mainly due to absorption and scattering **[**22**].** The apparent depth of the aerosol can be calculated by Angstrom exponent (AE) using the formula (1) [23]:

$$\tau_{\alpha\lambda} = \beta\lambda^{-AE} \qquad (1)$$

where λ is wavelength , β is turbidity coefficient and $\tau_{a\lambda}$ is the AOD at wavelength λ.

AE can be calculated according to the formula (2):

$$AE = -(d\ln \tau_{AE} / d\ln \lambda) = -[\ln(\tau_{AE2} / \tau_{AE1}) / \ln(\lambda 2 / \lambda 1)] \qquad (2)$$

where τ_{AE1} , τ_{AE2} are the AOD at wavelengths λ1, λ2**[**24**].**

Aerosol types:

Aerosol types can be determined based on many parameters, the most important of which are those that depend on aerosol load as AOD and particle size as AE [25] [26]. Aerosol classification to four different aerosol types includes maritime, dust, urban, and biomass burning [9] as shown in table (1).

Table (1) Aerosol classification based on AOD, AE

Aerosol Types	Aerosol Optical Depth (AOD)	Angstrom Exponent (AE)
Maritime	< 0.3	0.5-1.7
Dust	> 0.4	<1.0
Urban	0.2-0.4	>1.0
Biomass burning	> 0.7	>1.0

MATERIAL AND METHOD

In this research, we used MODIS/Aqua satellite data to obtain the aerosol changes over Syria during 2010 - 2020, and this data is available through the Giovanni website of NASA .The data we obtained from Giovanni was in the encrypted form nc, and to convert this data to numeric, we used Panoply and Java programs. Origin Lab used for maps of Syria, and SPSS for the statistical study [27].

3- RESULTS AND DISCUSSION

Aerosol Optical Depth (AOD):

The results of the annual changes of AOD over Syria (Aleppo, Homs, Damascus, Al Dear) which were obtained from the instrument MODIS installed on board Aqua satellite during 2010-2020, showed significant changes in the value of this parameter as shown in figure (4). As is clear from the figure, the large values of AOD were in Damascus, while the small values were in Aleppo, and the results showed low values 0.19 ± 0.006 during 2014.

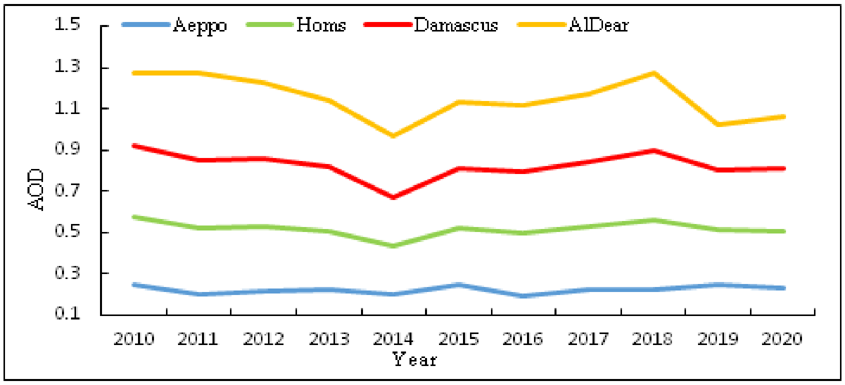


Figure (4) Annual changes of AOD over Syria during 2010 - 2020

Figure (5) shows the average monthly changes of AOD over Syria during 2010 - 2020, where the maximum values were 0.44 ± 0.091 in May and 0.395 ± 0.07 in September.

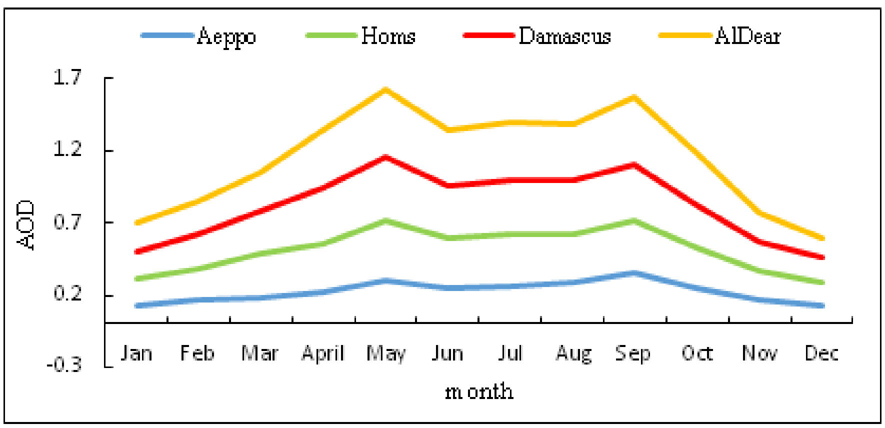


Figure (5) Average monthly changes of AOD over Syria during 2010 - 2020

While Figure (6) shows the monthly changes for AOD over Syria during 2010 – 2020. We notice from this figure that the largest value of AOD was 1.037 ± 0.072 during 2011.

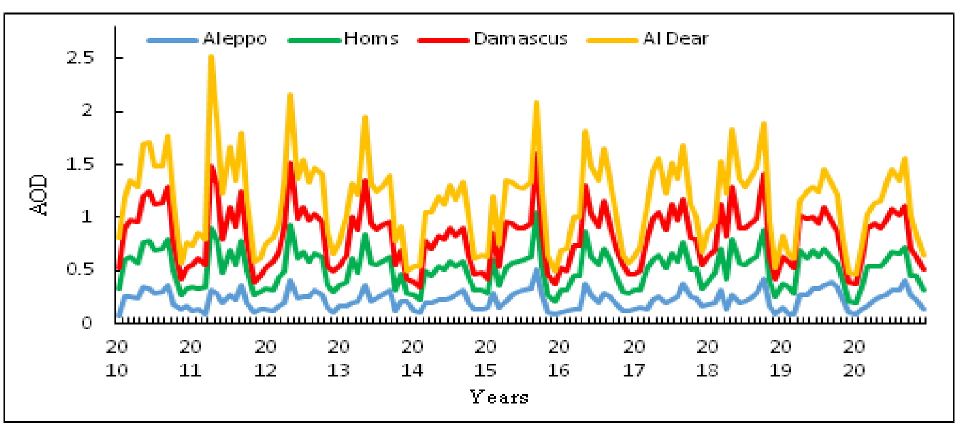


Figure (6) Monthly changes for AOD over Syria 2010 – 2020

In order to study the seasonal changes of AOD over Syria during 2010-2020, we used the program "Origin Lab" as shown in Figure (7), and as it is clear from the figure, the values of AOD were low in winter, then rise in spring and summer, after that decrease again during Autumn.

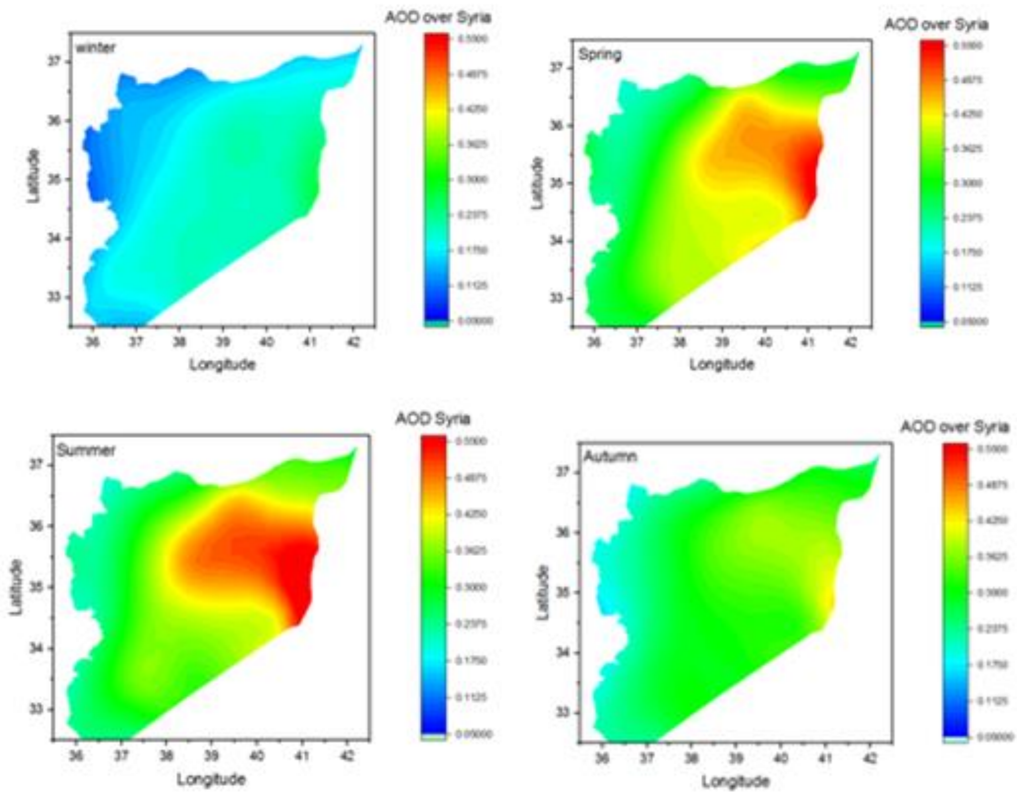
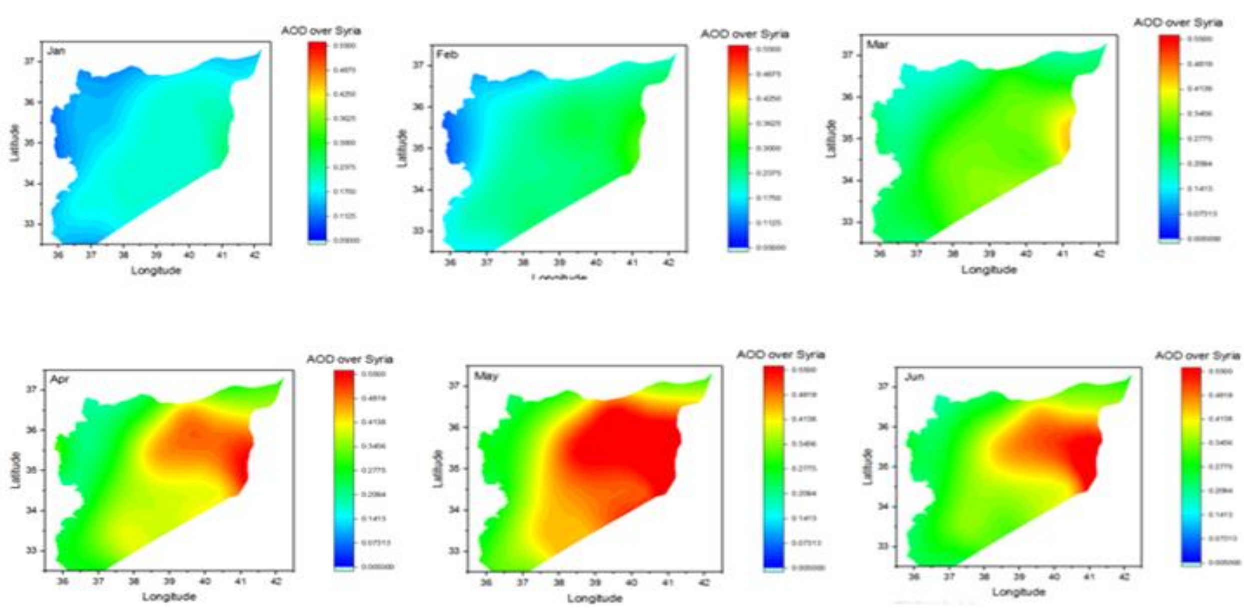


Figure (7) seasonal changes of AOD over Syria 2010-2020

While Figure (8) shows the monthly changes for AOD over Syria from 2010 – 2020. The highest value was in May, and the lowest value was in December.



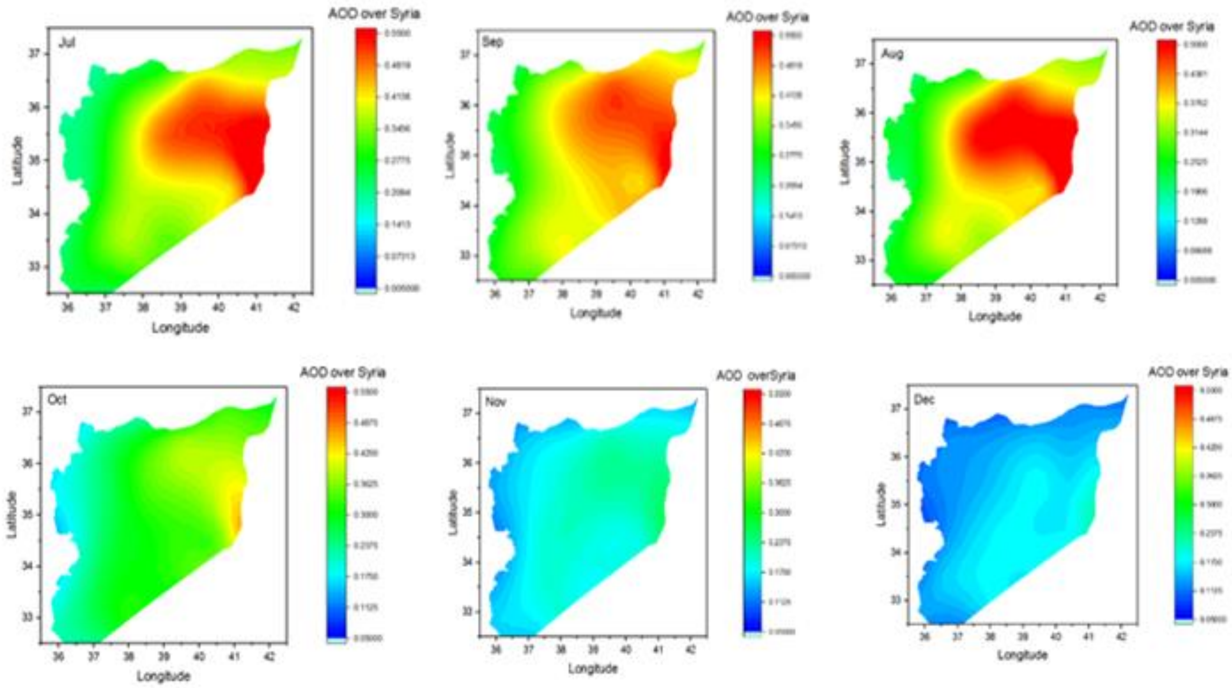


Figure (8) The monthly changes of AOD over Syria 2010 – 2020

Angstrom Exponent (AE):

In this research, we study the temporal and spatial changes of AE over Syria (Aleppo, Homs, Damascus, Al Dear) using MODIS Aqua satellite data. Figure (9) shows the annual changes of AE over Syria during 2010-2020. We notice from this figure that the large values of AE were over Al Dear, while the small values were over Aleppo, AE also shows low values over Syria during 2017 and high values during 2020.

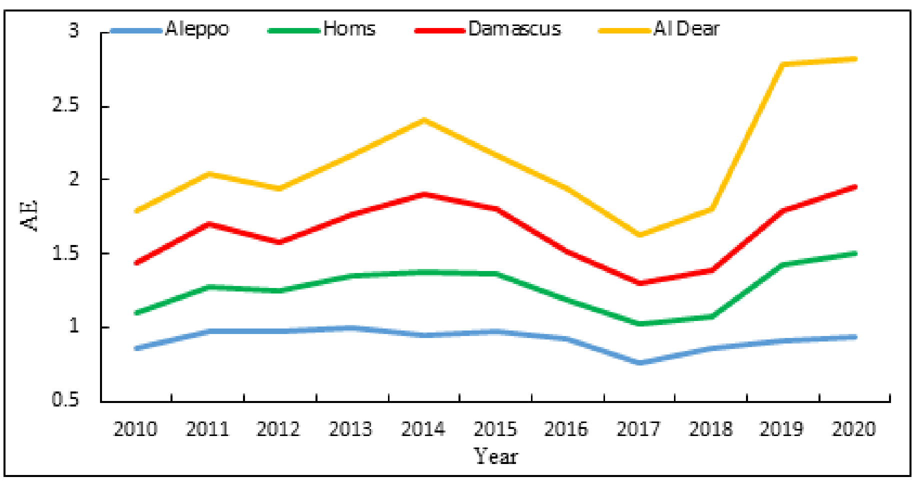


Figure (9) The annual changes of AE over Syria 2010-2020

While Figure (10) shows the average monthly changes AE over Syria during 2010 -2020, and as it is clear from the figure, the maximum values of AE were 0.89 ± 0.07, 0.839 ± 0.07 during January and December respecively, while the lowest value 0.42 ± 0.1 was in September.

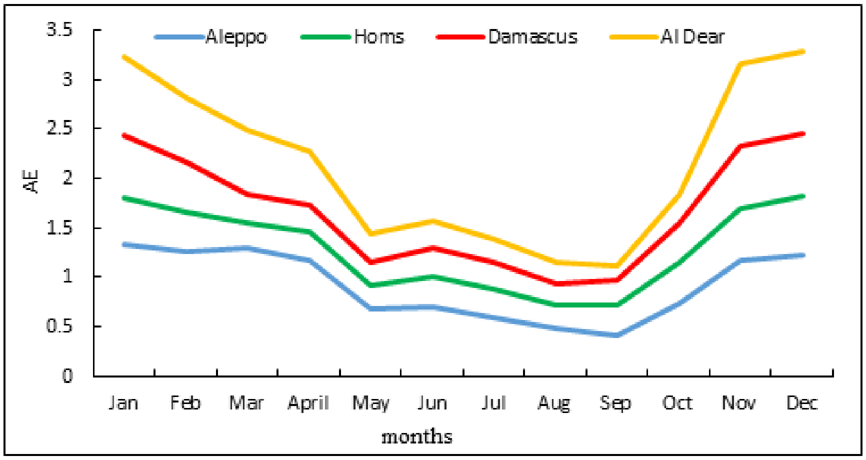


Figure (10) The average monthly changes of AE over Syria during 2010- 2020

Figure (11) also shows the monthly changes of AE over Syria during 2010 - 2020

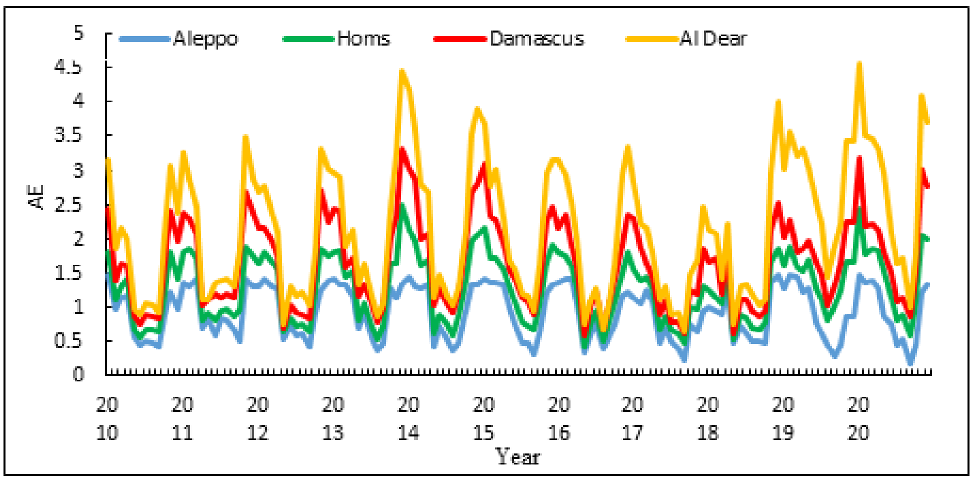


Figure (11) The monthly changes of AE over Syria during 2010- 2020

In order to study the seasonal changes of AE over Syria during 2010-2020, we used the program "Origin Lab" as shown in Figure (12), and as it is clear from the figure, the values of AE were low in summer, and large in winter.

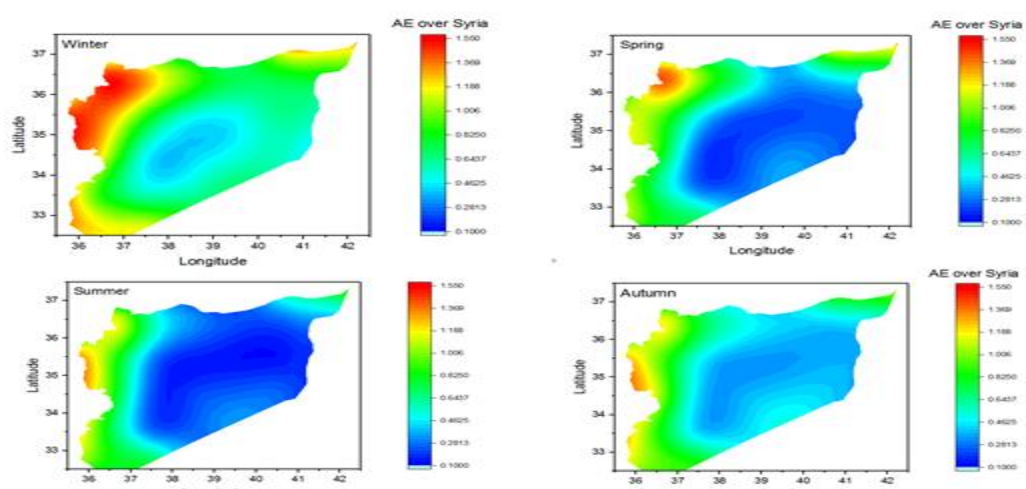


Figure (12) seasonal changes of AE over Syria during 2010-2020

Finally, Figure (13) shows the monthly changes of AE over Syria during 2010 - 2020 using the program Origin Lab, the maximum values were during December and January, while the minimum values were in August and September

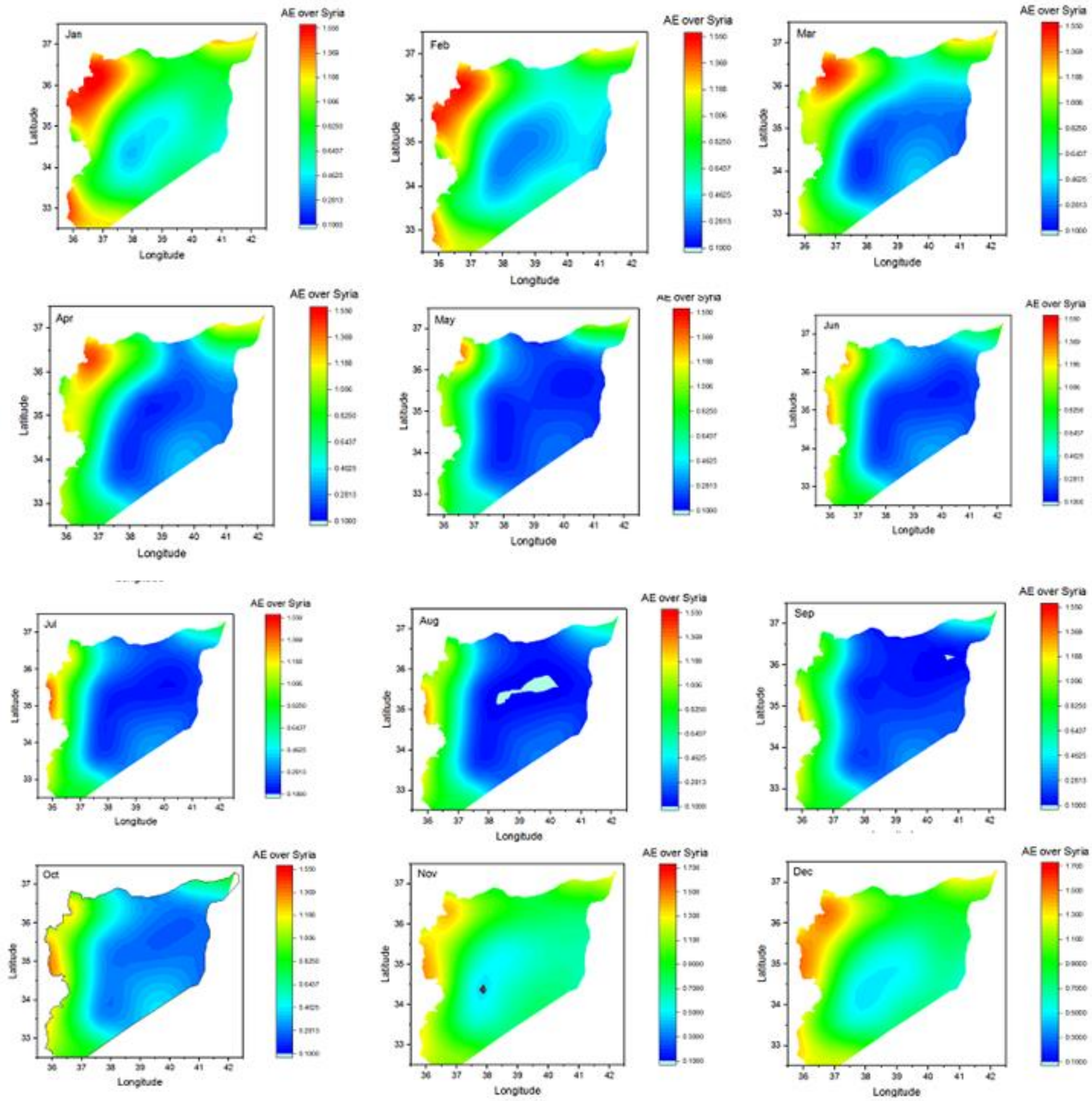


Figure (13) The monthly changes of AE over Syria during 2010 – 2020

Classification of aerosols over Syria during 2010 – 2020:

Aerosols can be classified based on AOD and AE values to 4 types (maritime, dust, urban, and biomass burning) according to Table 1. The results showed that the aerosol over Syria is largely composed of maritime and lowest from biomass-burning, as shown in figure (14).

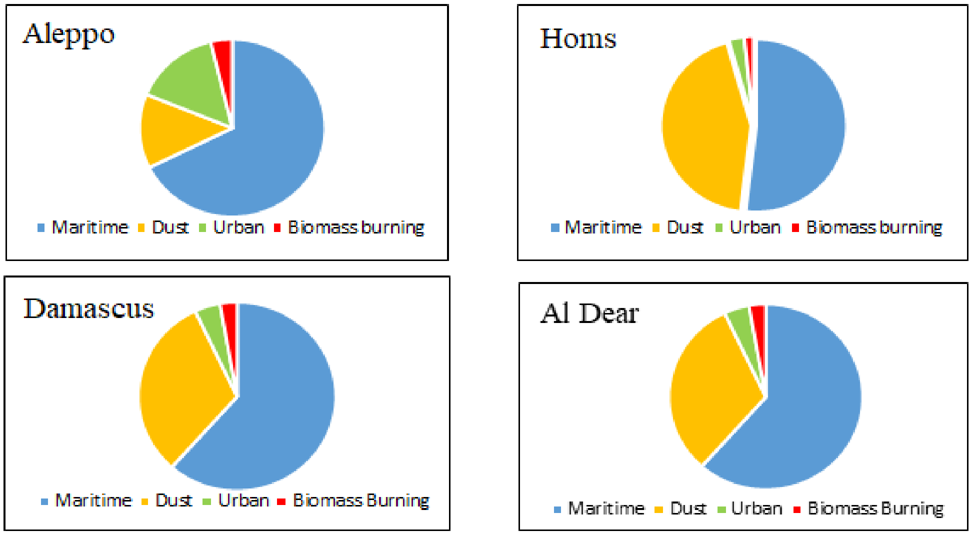


Figure (14) Classification of aerosols over Syria during 2010 – 2020

Finally, the statistical study was carried out using the SPSS program, table 2 and 3, show the minimum values, maximum values, Std. error and Std. deviation of the monthly and annual AOD values, respectively over Syria during 2010-2020.

Table 2: Minimum, maximum values, Std. error and Std. deviation for monthly AOD over Syria during 2010-2020.

Station	Minimum value	Maximum value	Std. Deviation	Std. Error
Aleppo	0.13	0.36	0.071	0.020
Homs	0.16	0.42	0.081	0.023
Damascus	0.17	0.44	0.026	0.091
Al Dear	0.14	0.47	0.032	0.011

Table 3: Minimum, maximum values, Std. error and Std. deviation for annual AOD over Syria during 2010- 2020.

Station	Minimum value	Maximum value	Std. Deviation	Std. Error
Aleppo	0.19	0.25	0.020	0.006
Homs	0.24	0.34	0.031	0.0091
Damascus	0.23	0.34	0.030	0.0092
Al Dear	0.22	0.42	0.056	0.017

Table 4 and 5,show the minimum values, maximum values, Std. error and Std. deviation of the monthly and annual AE values, respectively over Syria during 2010-2020.

Table 4: Minimum, maximum values, Std. error and Std. deviation for monthly AE over Syria during 2010-2020.

Station	Minimum value	Maximum value	Std. Deviation	Std. Error
Aleppo	0.42	1.34	0.349	0.100
Homs	0.21	0.59	0.133	0.038
Damascus	0.22	0.63	0.165	0.047
Al Dear	0.15	0.89	0.271	0.078

Table 5: Minimum, maximum values, Std. error and Std. deviation for annual AE over Syria during 2010-2020.

Station	Minimum value	Maximum value	Std. Deviation	Std. Error
Aleppo	0.77	1	0.069	0.020

Homs	0.22	0.56	0.113	0.034
Damascus	0.28	0.52	0.072	0.022
Al Dear	0.32	0.99	0.226	0.068

SUMMARY

Eleven years of high quality satellite derived aerosol optical depth (AOD) and Angstrom Exponent (AE) data have been used for the first time over Syria. This study was an attempt to analyze the temporal and spatial distribution of AOD and AE over Syria using MODIS /Aqua satellite data in the period 2010-2020. The results indicate that both AOD and AE were large in Al Dear and small in Aleppo. The average monthly changes of AOD show that the maximum values were 0.44 ± 0.091 in May and 0.395 ± 0.07 in September, and the values of AOD were low in the winter and autumn and rise in spring and summer. As for the results of AE, it showed the opposite behavior of AOD. The results of the average monthly changes AE showed that the maximum values of AE were 0.89 ± 0.07, 0.839 ± 0.07 during January and December respecively, while the lowest values was 0.42 ± 0.1 in September and the values of AE were low in summer, and large in winter. Finally, aerosols classified based on AOD and AE values and the results showed that the aerosol over Syria is largely composed of maritime and lowest from biomass-burning.

ACKNOWLEDGMENT

The authors wish thanks for the National Aeronautics and Space Administration (NASA) for providing the MODIS /Aqua data that was used in this research.

REFERENCES

1- Saxena, P., & Naik, V. (Eds.). (2018). Air pollution: sources, impacts and controls. Cabi.

2- Laj, P., Bigi, A., Rose, C., Andrews, E., Lund Myhre, C., Collaud Coen, M., ... & Zikova, N. (2020). A global analysis of climate-relevant aerosol properties retrieved from the network of Global Atmosphere Watch (GAW) near-surface observatories. Atmospheric Measurement Techniques, 13(8), 4353-4392.

3- Salby, M. L. (1996). Fundamentals of atmospheric physics. Elsevier.

4- Fleagle, R. G., & Businger, J. A. (1981). An introduction to atmospheric physics. Academic Press.

5- Abbood, Z. M., & Al-Taai, O. T. (2018). Study of absorbance and emissivity solar radiation by clouds, aerosols and some atmospheric gases. Journal of Applied and Advanced Research, 3(5), 128-134.

6- Patel, M. P., & Application, S. (2016). Study of Aerosol Optical Depth and Black Carbon concentration over Dehradun and surroundings. Indian Institute of Remote Sensing,(ISRO).

7- Prather, K. A., Hatch, C. D., & Grassian, V. H. (2008). Analysis of atmospheric aerosols. Annu. Rev. Anal. Chem., 1, 485-514.

8- Várnai, T., & Marshak, A. (2021). Analysis of Near-Cloud Changes in Atmospheric Aerosols Using Satellite Observations and Global Model Simulations. Remote Sensing, 13(6), 1151.

9- Al-Salihi, A. M. (2018). Characterization of aerosol type based on aerosol optical properties over Baghdad, Iraq. Arabian Journal of Geosciences, 11(20), 1-15.

10- Solomos, S., Ansmann, A., Mamouri, R. E., Binietoglou, I., Patlakas, P., Marinou, E., & Amiridis, V. (2017). Remote sensing and modelling analysis of the extreme dust storm hitting the Middle East and eastern Mediterranean in September 2015. Atmospheric Chemistry and Physics, 17(6), 4063-4079.

11- Pu, B., & Ginoux, P. (2016). The impact of the Pacific Decadal Oscillation on springtime dust activity in Syria. Atmospheric Chemistry and Physics, 16(21), 13431-13448.

12- Peyridieu, S., Chédin, A., Tanré, D., Capelle, V., Pierangelo, C., Lamquin, N., & Armante, R. (2010). Saharan dust infrared optical depth and altitude retrieved from AIRS: a focus over North Atlantic–comparison to MODIS and CALIPSO. Atmospheric Chemistry and Physics, 10(4), 1953-1967.

13- Mahmood, I., Iqbal, M. F., Shahzad, M. I., Waqas, A., & Atique, L. (2016). Spatiotemporal monitoring of CO2 and CH4 over Pakistan using Atmospheric Infrared Sounder (AIRS). International Letters of Natural Sciences, 58.

14- Yousefi, R., Wang, F., Ge, Q., Lelieveld, J., & Shaheen, A. (2021). Aerosol Trends during the Dusty Season over Iran. Remote Sensing, 13(6), 1045.

15- Kannemadugu, H. B. S., Varghese, A. O., Mukkara, S. R., Joshi, A. K., & Moharil, S. V. (2015). Discrimination of aerosol types and validation of MODIS aerosol and water vapour products using a sun photometer over Central India. Aerosol and Air Quality Research, 15(2), 682-693.

16- Parkinson, C. L. (2003). Aqua: An Earth-observing satellite mission to examine water and other climate variables. IEEE Transactions on Geoscience and Remote Sensing, 41(2), 173-183.

17- B. AL-Taie, K., Rajab, J. M., & Al-Salihi, A. M. (2020, December). Climatology and classification of aerosols based on optical properties over selected stations in Iraq. In AIP Conference Proceedings (Vol. 2290, No. 1, p. 050041). AIP Publishing LLC.

18- Gupta, P., Khan, M. N., da Silva, A., & Patadia, F. (2013). MODIS aerosol optical depth observations over urban areas in Pakistan: quantity and quality of the data for air quality monitoring. Atmospheric pollution research, 4(1), 43-52.

19- Várnai, T., & Marshak, A. (2021). Analysis of Near-Cloud Changes in Atmospheric Aerosols Using Satellite Observations and Global Model Simulations. Remote Sensing, 13(6), 1151.

20- Battour, F., & Alzamil, T. (2021). Spatiotemporal Of Carbon Dioxide And Methane Observation Over Syria Using Airs/Aqua During 2003-2016. European Journal of Molecular & Clinical Medicine, 7(8), 5450-5458.

21- Climate-Change Atlas of Syria .Technical Report · January 2010. DOI: 10.13140/RG.2.2.26562.17601.

22- Liu, M., Westphal, D. L., Walker, A. L., Holt, T. R., Richardson, K. A., & Miller, S. D. (2007). COAMPS real-time dust storm forecasting during Operation Iraqi Freedom. Weather and forecasting, 22(1), 192-206.

23- Pedrós, R., Martinez-Lozano, J. A., Utrillas, M. P., Gómez-Amo, J. L., & Tena, F. (2003). Column-integrated aerosol optical properties from ground-based spectroradiometer measurements at Barrax (Spain) during the Digital Airborne Imaging Spectrometer Experiment (DAISEX) campaigns. Journal of Geophysical Research: Atmospheres, 108(D18).

24- Eck, T. F., Holben, B. N., Reid, J. S., Dubovik, O., Smirnov, A., O'neill, N. T., ... & Kinne, S. (1999). Wavelength dependence of the optical depth of biomass burning, urban, and desert dust aerosols. Journal of Geophysical Research: Atmospheres, 104(D24), 31333-31349.

25- Bayat, A., Masoumi, A., & Khalesifard, H. R. (2011). Retrieval of atmospheric optical parameters from ground-based sun-photometer measurements for Zanjan, Iran. Atmospheric Measurement Techniques, 4(5), 857-863.

26- Kim, J., Lee, J., Lee, H. C., Higurashi, A., Takemura, T., & Song, C. H. (2007). Consistency of the aerosol type classification from satellite remote sensing during the Atmospheric Brown Cloud–East Asia Regional Experiment campaign. Journal of Geophysical Research: Atmospheres, 112(D22).

27- Alzamil T, Battour F., 2020-Temporal and spatial distribution of tropospheric CO2 over Aleppo based on AIRS during 2003-2016.PROCEEDING BOOK.2nd International Eurasian Conference on Science, Engineering and Technology (EurasianSciEnTech2020),October07-09,Gaziantep/ Turkey. ISBN: 978-60569426-2-4.pag 917-921.