Journal of Education for Pure Science- University of Thi-Qar
Vol.9, No.2 (June, 2019)
Website: jceps.utq.edu.iq Email: jceps@eps.utq.edu.iq

DOI: http://doi.org/10.32792/utq.jceps.09.02.26

Optical Properties of Aerosols over Urban and Desert Areas

Dheyaa A. Bilal

College of Education for pure Sciences, University of Thi Qar, Thi Qar, Iraq.

Received 05/02/2019, Accepted 21/05/2019, Published 02/06/2019

Abstract:

The atmosphere aerosols play an important role in the physical processes occur in the atmosphere. Such as absorption and scattering of solar radiation and formation of cloud and precipitation. Consequently, aerosols affect the radiation balance and water balance of atmosphere. Therefore, the study of optical properties of aerosol is very important in many applications such as modeling of solar radiation, cloud modeling and climate modeling. The aim of this research is to investigate the aerosols optical properties using the Optical Properties Aerosol and Cloud (OPAC) software package. Three types of aerosols were considered, namely continental, desert, and urban aerosols. The results indicated that the optical properties of aerosols (extinction, scattering, absorption coefficients; single scattering albedo; asymmetric parameter, and optical depth) in general decreases with increasing wavelengths but they decrease sharply at shorter wavelength and gradually at longer wavelengths. In addition, the effect of atmospheric windows is evident in the 5-10 µm range of the spectrum. The results also suggested that desert aerosols are the most effective type followed by urban and continental polluted aerosols. Change in relative humidity can affect the optical properties of the continental and urban aerosols while the desert aerosols are almost unaffected by the change of relative humidity.

Key wads: Optical Properties, Aerosols, Desert areas.

Introduction

Aerosol known as minutes of solid and liquid substances such as dust and pollen granules cloud droplets [1]. Examples of aerosol particles emitted into the atmosphere are liquid or solid particles produced by biomass combustion, dust from volcanic activities, soot, sea salt, and smoke, as well as conversion of gas molecules in the atmosphere such as nitrite, sulphate and some organic material [2][3]. Aerosols play an important role in the physical processes that occur in the atmosphere through numerous operations including dispersion (Scattering), reflection (Albedo) and absorption of solar radiation [4].
This role depends on the size of aerosol particles and their chemical nature. The presence of aerosols in the atmosphere cools the earth's surface and the air adjacent to this surface because these particles tend to reflect the incoming solar radiation towards outer space. Aerosols also act as cloud condensation nuclei to

from cloud droplets which grow via different processes to fall towards earth surface as precipitation particles [5]. Aerosols have a residence time in the atmosphere and this time depends on their size such that large particles remain suspended in the atmosphere for a few days, while the particles with size of 0.1 micron or less remain suspended in the lower troposphere for a couple of weeks [6]. Aerosols from sources near earth surface are driven by surface wind and spreads upwards by disturbances that occur near the surface of the Earth. When aerosols are close to the clouds they will be carried into the cloud by convection. Dispersion of aerosols in the stratosphere are controlled by the general circulation and exchange mechanisms the tropopause.

There are many researchers who studied the subject of aerosol optical properties. Kenneth et al., (2003) [7] studied the indirect effects of desert aerosol and dust storms on clouds using airborne polarization lidar. Toledano et al., (2009) [8] studied the characteristics of aerosol spectral optical depths of desert dust in Morocco for the year 2006, where they monitor the aerosol optical depth in the range 1550-340 nm. They used two types of measuring devices for solar radiation and found that Aerosol Optical Depth (AOD) at 500 nm was 0.28. Veroustraete et al., (2010) [9] used remote sensing techniques to monitor aerosols optical depth and determine aerosol size distribution in Belgium. Kim et al., (2011) [10] worked on dust optical properties in North Africa and Arabian Peninsula and concluded that optical depth is large during dusty days and annual means of scattering coefficient, reflection, asymmetric parameter, and refractive index were 0.964±0.005, 0.752±0.0114, 1.498±0.032, and 0.0025±0.0036. Khoshsima et al.,

(2014) [11] investigated aerosol optical properties including aerosol optical depth , Angstrom exponent and Angstrom turbidity coefficient during December 2009 to October 2010, in a suburban area of Zanjan in Iran. They showed that turbidity varies on all time scales, from the seasonal to hourly, because of changes in the atmospheric meteorological parameters. Gharibzadeha et al., (2017) [12] studied aerosol optical properties and radiative forcing over Zanjan in northwest of Iran has been during 2010–2013. Rezaei et al., (2018) [13] examined temporal and spatial characteristics of aerosol properties and classify their modes over Iran. Al-Salihi (2018) [14] analyzed and classified aerosol types over Baghdad city in Iraq for eight years period. He also used a Hybrid Single-Particle Lagrangian Integrated Trajectory model to determine the source of air mass transport and to recognize the variability of aerosol origin regions.

Theoretical Consideration

Optical Properties of Aerosols and Clouds (OPAC) software package provides calculations of the optical properties of aerosols and clouds in certain wavelengths ranges from 0.25 to 40 μm for aerosols and water clouds and from 0.28 to 40 μm for ice clouds [15]. Calculations of these properties were based on Mie scattering theory [16] The optical properties of aerosols and clouds arranged in OPAC file and be stored separately in ASCII files for each type of aerosols or clouds and certain relative humidity. These properties are [15]:

1. Extinction coefficient σ_e^1 (km^{-1})
2. Scattering coefficient σ_a^1 (km^{-1})
3. Absorption coefficient σ_a^1 (km^{-1})
4. Single scattering albedo $\overline{\omega_o}$

5. Asymmetric parameter g
6. Optical depth

The extinction, scattering, and absorption coefficients are normalized to a number density of 1particle per cm^3. The absolute value for these coefficients can be calculated by multiplying their normalized values by the total particle density.

The aerosol optical depth τ is calculated from the extinction coefficient of the selected aerosol type in combination with the height profile N(h) which is predefined in OPAC or given by the user for four discrete layers:

$$\tau = \sum_j \int_{H_{j,\min}}^{H_{j,\max}} \sigma_{e,j}(h)dh = \sum_j \sigma^1_{e,j} N_j(0) \int_{H_{j,\min}}^{H_{j,\max}} e^{-\frac{h}{Z_j}} dh \qquad (1)$$

where $\sigma^1_{e,j}$ is the extinction coefficient of the aerosol or cloud in layer j, normalized to 1 particle per cm^3. H, h, and Z are the height profile variables.

The visibility (km) is calculated as follows

$$vis = \frac{3.0}{\sigma_e(0.55\ \mu\text{m}) + \sigma_M(0.55\ \mu\text{m})} \qquad (2)$$

The constant 3.0 represents the real observer visibility (Gorden, 1970) [16]. The coefficient σ_M is the extinction coefficient due to air molecules at $0.55\ \mu\text{m} = 0.01159\ (\text{km}^{-1})$ at sea level pressure (1013 hPa)

In this work only continental, desert, and urban aerosols types are considered. The following paragraphs give a short description of these types:

Continental clean aerosol represents remote continental areas without or with very low anthropogenic influences and consequently low amount of soot.

Continental average aerosol is used to describe anthropogenic influence in continental areas and therefore it contains soot and an increased amount of the insoluble and water-soluble components.

Continental polluted aerosol is for areas highly polluted by man-made activities and therefore it contain more soot and water-soluble.

Urban aerosol represents strong pollution in urban areas which has large amount of soot and both water-soluble substance and insoluble. Such type of aerosols are found in center areas of large cities.

Desert aerosol is used to describe aerosol over all deserts of the world. It consists of the mineral aerosol components in a combination that is representative for average turbidity, together with a certain part of the water-soluble component.

Results and Discussion

The optical properties have been extracted and calculated from OPAC software package for wavelengths range from 0.25 to 40 µm for the three type of aerosols, continental, urban, and desert. Figure 1 shows the optical properties as a function of wavelength for relative humidity of 0%. It is seen that the extinction, scattering, and absorption coefficients have similar behavior with wavelength. Also the optical depth behaves like the three coefficients. The behavior is that the values of these properties decreases with increasing wavelength in the region of short wavelengths. The increasing and decreasing peaks in the

visible range are due to the presence of atmospheric windows. At longer wavelength, the properties tend to decrease gradually indicating weak dependencies on wavelength. The results also show that the desert aerosols are the most effective type followed by urban and continental aerosols. Among continental aerosols, polluted type is most effective followed by average and clean type. It can also be seen that at shorter wavelength, the higher single scattering albedo comes from desert aerosols and at higher wavelengths it comes from continental clean aerosols. At wavelengths higher than 30 µm desert aerosols again gives highest value of single scattering albedo. The asymmetric parameter is the same for all types of aerosols except desert aerosols where it is lower. Figure 2 shows the visibility as function of relative humidity for the five types of aerosols. The results indicate that the best visibilities are associated with continental clean aerosols while worst visibilities caused by urban aerosols. Visibility decreases gradually with increasing relative humidity for values less than about 80% and then decreases sharply beyond these values. This suggests that very high relative humidity plays an important role in degrading the visibility. Figure 3 illustrates the number, mass, and volume mixing ratios of different components of given type of aerosols. The mixing ratio is the ratio of specific component to the total components of given aerosols. The results reflects that for continental average aerosols, soot has the highest number mixing ratio and insoluble materials has the lowest number mixing ratio. Insoluble and water soluble materials have similar mass and volume mixing ratios (about 0.45) while soot has very low mass and mixing ratios. For continental clean, water soluble component has a mixing ratio of 1.0 and insoluble has very small mixing ratio. The mass and volume mixing ratios are similar for both components (about 0.45). The pattern of mixing ratios for the continental polluted are similar to those of the continental average but mass and volume mixing rations of insoluble component are less than those of water soluble aerosols. For desert aerosols,
water soluble components has very high number mixing ratio but very low mass and volume mixing ratios while the component of the mineral accumulated mode has very low number mixing ratio and high mass and volume mixing ratios. The mineral normal mode has a number mixing ratio of 0.1 but mass and volume mixing ratios of 0.04. The urban type of aerosols has a number mixing ratio of 0.8 and less than 0.15 mass and volume mixing ratios. Insoluble and water soluble components has comparable mass and volume mixing ratios but the number mixing ratio of insoluble is very small. Figures 4, 5, and 6 give the effect of relative humidity on the optical properties for continental average, desert, and urban aerosols respectively. The results show that for continental average and urban aerosols (figures 4 and 6), the extinction, scattering, and absorption coefficients along with optical depth increases with increasing relative humidity while the single scattering albedo and asymmetric parameter are inversely proportional with relative humidity. The effect becomes larger when relative humidity is greater than 90%. The optical properties of desert aerosols (figure 5) are almost independent of relative humidity.

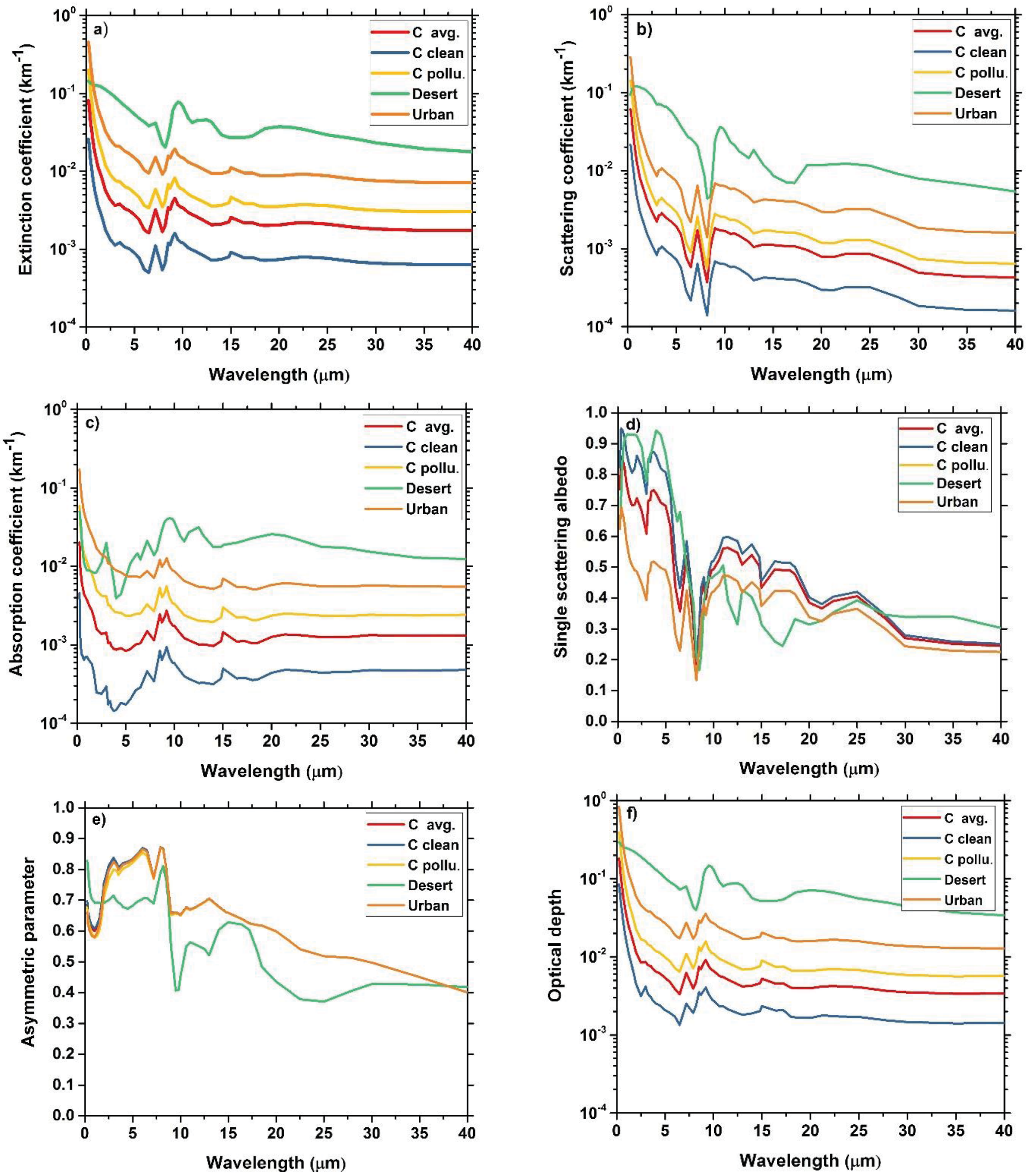


Figure 1: Optical properties of different types of atmospheric aerosols: a) extinction coefficient, b) scattering coefficient, c) absorption coefficient, d) single scattering albedo, e) asymmetric parameter, f) optical depth.

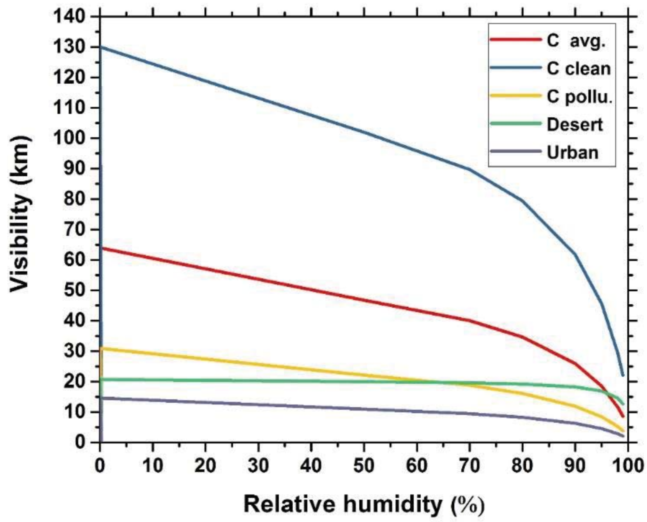
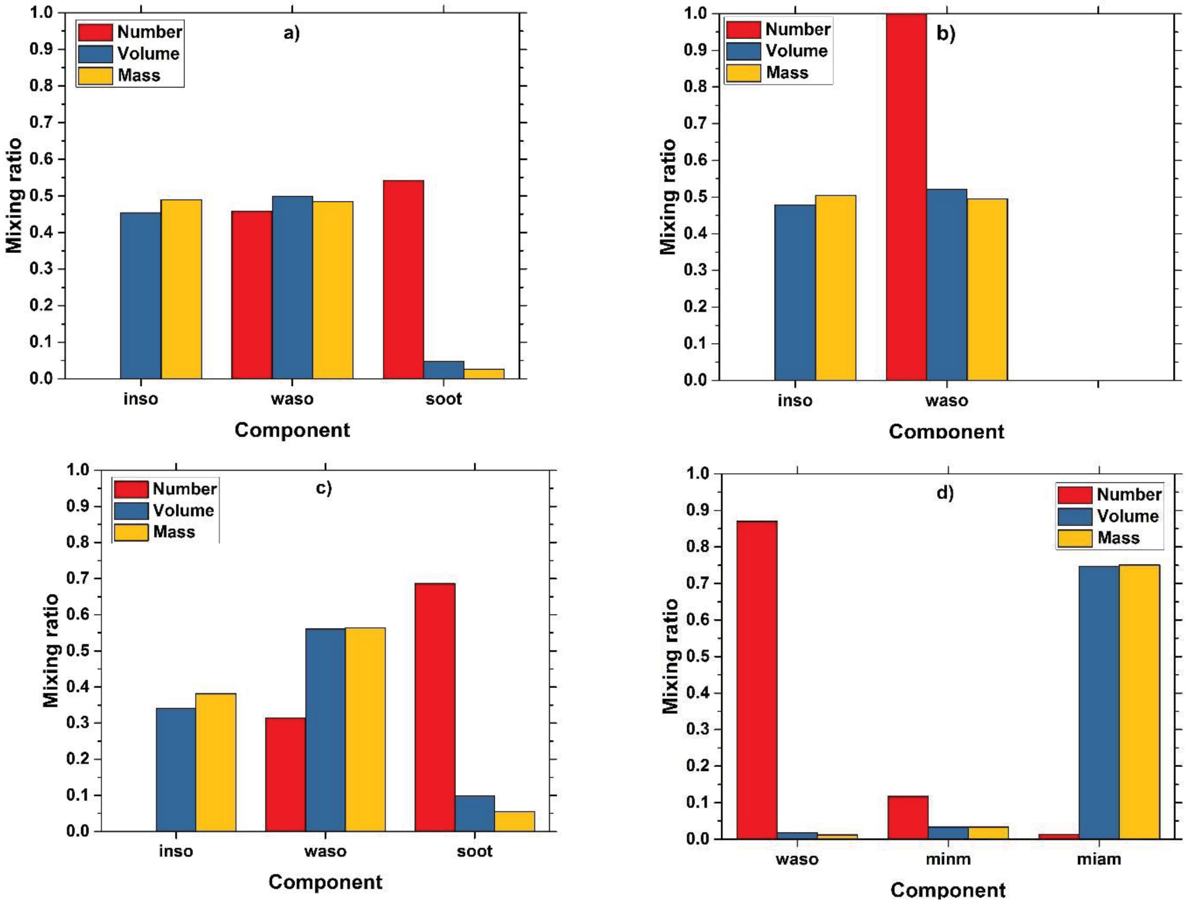


Figure 2: Visibility versus relative humidity for different types of atmospheric aerosols.



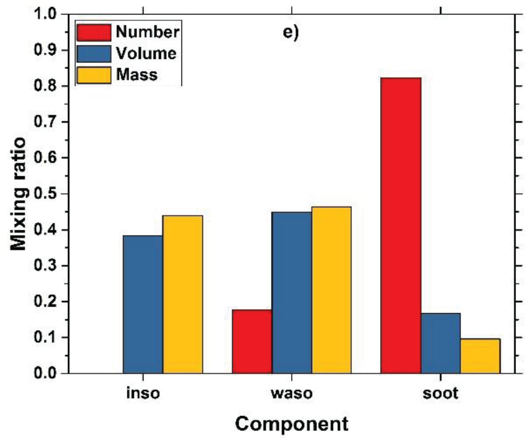
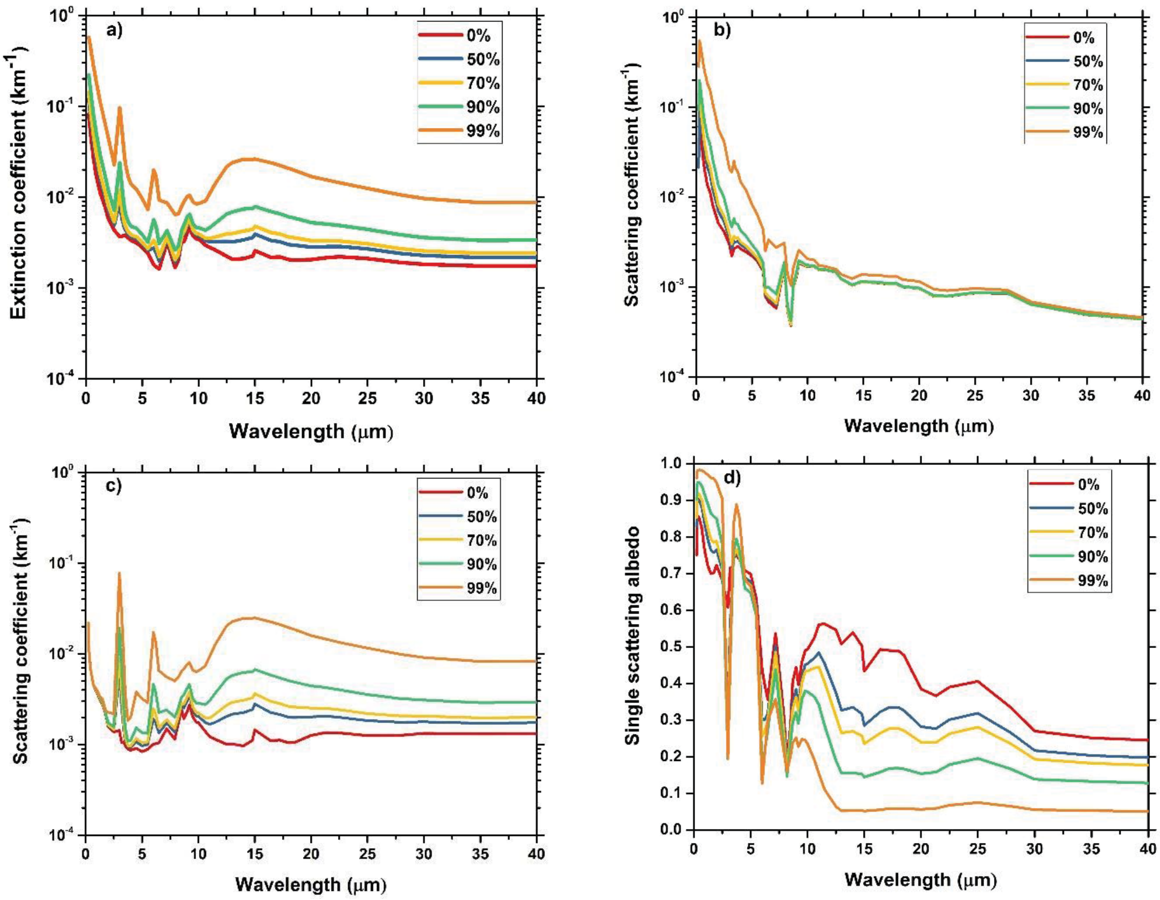


Figure 3: Number, volume, and mass mixing ratios of material components for atmospheric aerosols: a) continental average, b) continental clean, c) continental polluted, d) desert, e) urban. inso: insoluble; waso: water-soluble; minm: mineral (nuclei mode); miam: mineral (accumulation mode)



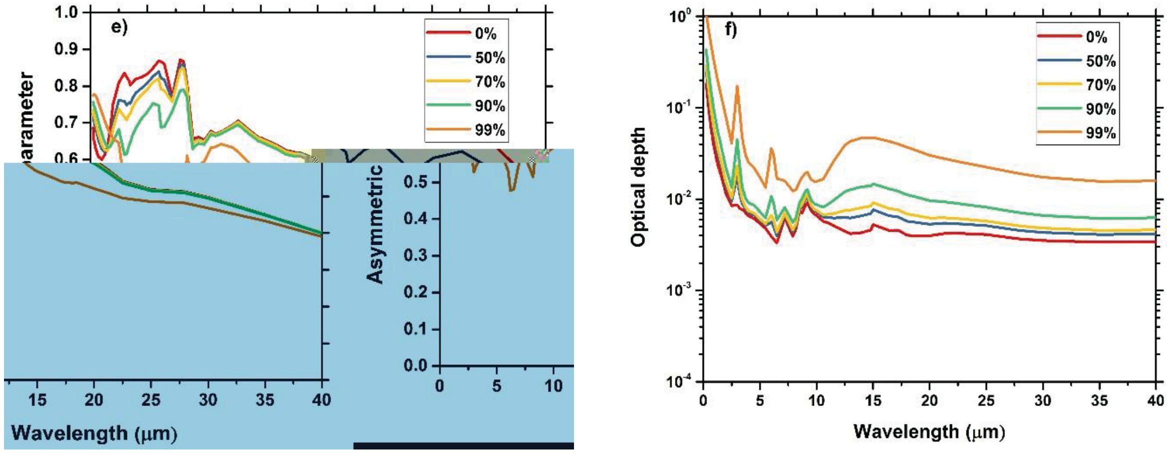
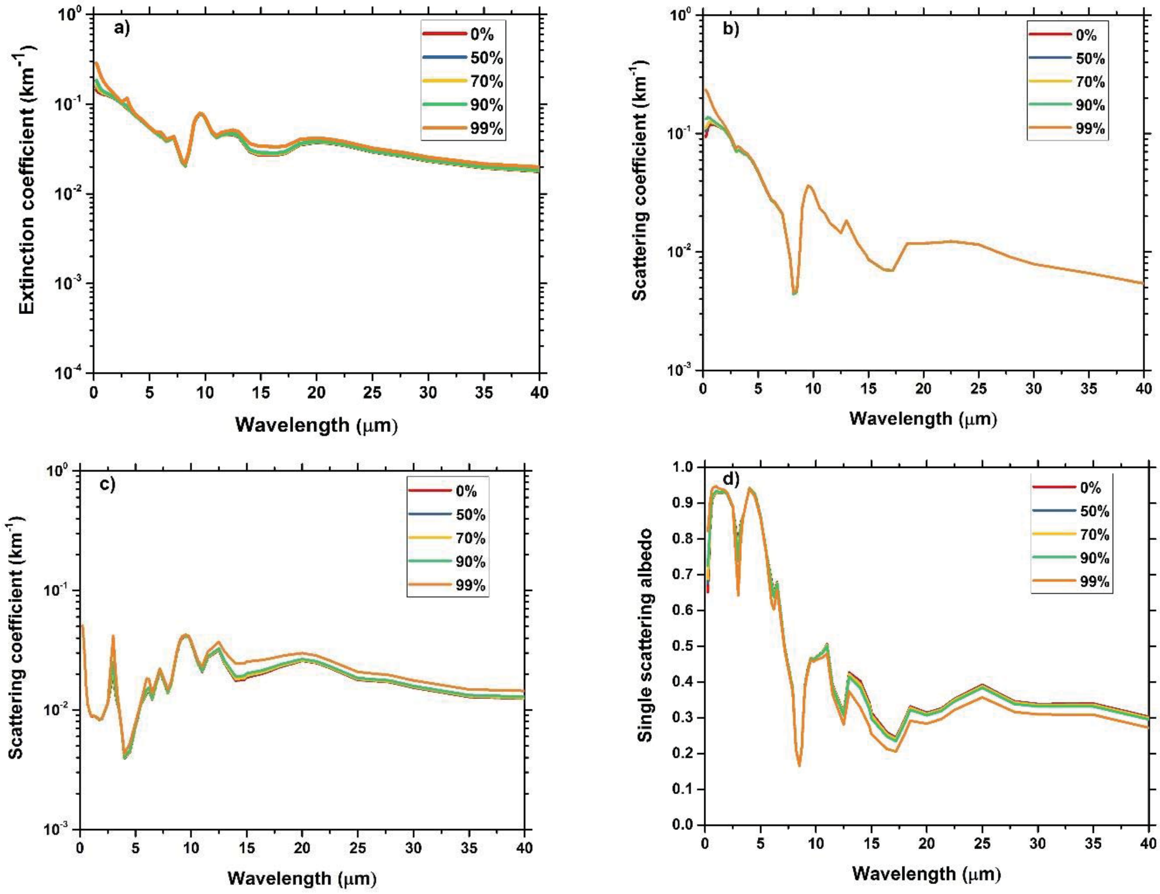


Figure 4: Optical properties of continental average atmospheric aerosols for different relative humidity: a) extinction coefficient, b) scattering coefficient, c) absorption coefficient, d) single scattering albedo, e) asymmetric parameter, f) optical depth.



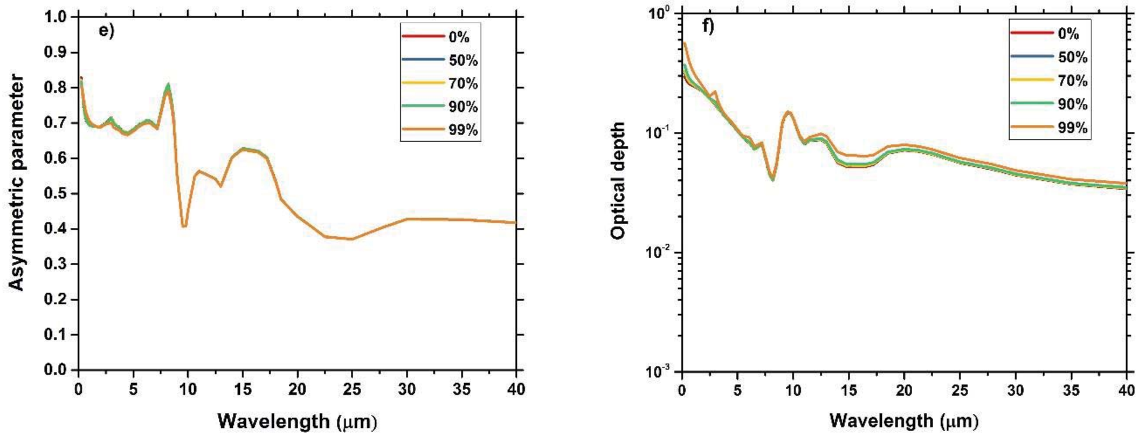
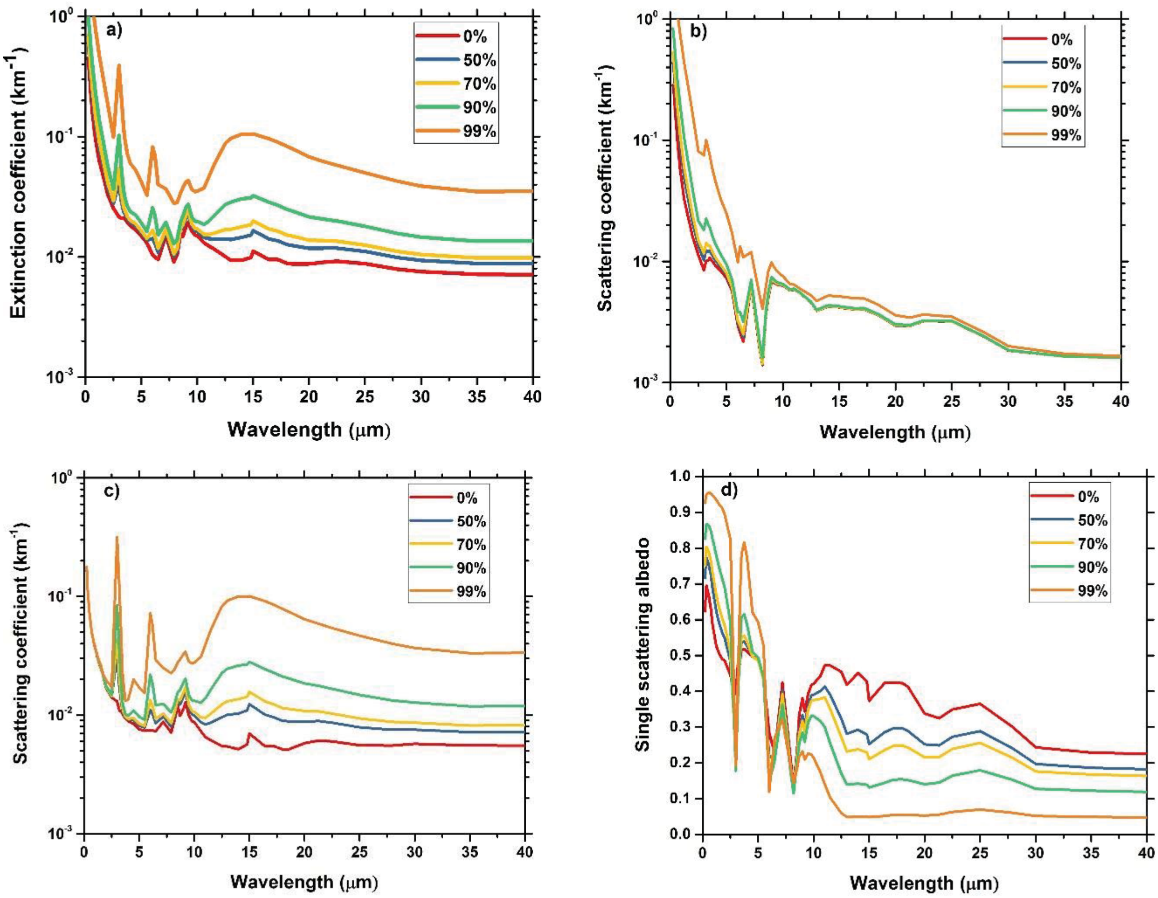


Figure 5: Same as figure 4 desert atmospheric aerosols: a) extinction coefficient, b) scattering coefficient, c) absorption coefficient, d) single scattering albedo, e) asymmetric parameter, f) optical depth.



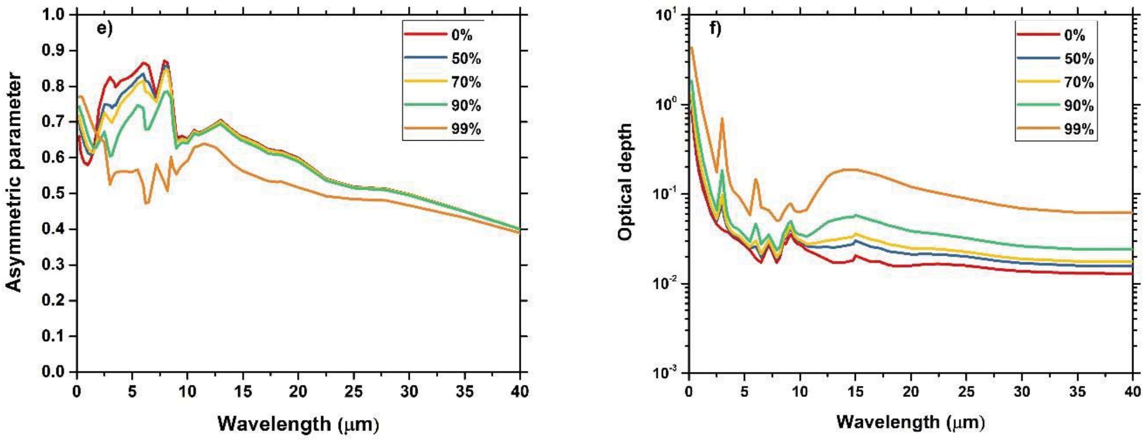


Figure 6: Same as figure 4 but for urban atmospheric aerosols: a) extinction coefficient, b) scattering coefficient, c) absorption coefficient, d) single scattering albedo, e) asymmetric parameter, f) optical depth.

Conclusion

This work used OPAC software package to extract and calculate the optical properties of three types of aerosols. Namely continental (clean, average, and polluted), desert, and urban. The following were concluded from the results of this work:

- The optical properties; extinction, scattering, and absorption coefficients; single scattering albedo, asymmetric parameter, and optical depth are inversely related to wavelengths.
- Visibly is almost independent of changes in low values of relative humidity and reduces as relative humidity increases and this reduction depends on the type of areoles.
- Higher values of optical properties results from desert aerosols followed by urban and continental polluted aerosols.
- Relative humidity can affect the optical properties of continental and urban aerosols but has negligible effect on the desert aerosols.

References:

1. Andreae. M. H. Annegarn, L. Barrie, J. Feichter, D. Hegg, A. Jayaraman, R. Leaitch, D. Murphy, J. Nganga, G. Pitari, , 2001: Aerosols their Direct and Indirect Effects. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, 289-348.
2. Baron. P. 2006: Generation and Behavior of Air-borne Particles (Aerosols), National Institute of of tropospheric aerosol over land from EOS moderate resolution imaging spectroradiometer. J. Geophys. Res, 102 (17): 051–17.
3. Ranite. L. A. R. W., Perkins, T. M., Tanner and C.W., Towmas, 1970: Stable Elements of the Atmosphere as Tracers of Precipitation. Scavenging Preccedings of a Sumposium Held at Richland, Washington, June 2-4 1970, 99-108.
4. Ogren. J. A. J.A. Ogren, E. Andrews, A. McComiskey, P. Sheridan, A. Jefferson, and M. Fiebig, 2006: New Insights into Aerosol Asymmetry Parameter, National Oceanic and Atmospheric Administration/Earth System Research Laboratory
5. Davies, C. V, 1987: Particle in the Atmosphere: A Review, J. Aerosol Sci, 18,5 469- 477.

6. Cotton. W. R., 1979: *Human Impact on Weather and Climate*: 2nd Edition, Cambridge Univesity Press.
7. Kenneth Sassen, Paul J. DeMott, Joseph M. Prospero, and Michael R. Poellot, 2003: Saharan dust storms and indirect aerosol effects on clouds: CRYSTAL-FACE results, GEOPHYSICAL RESEARCH LETTERS, Vol. 30, No. 12, 1633, doi:10.1029/2003GL017371.
8. Toledano, C & Wiegner, M & Garhammer, M & Seefeldner, Meinhard & Gasteiger, J & Müller, Detlef & Koepke, Peter. (2009). Spectral aerosol optical depth characterization of desert dust during SAMUM 2006. Tellus B. 61. 10.3402/tellusb.v61i1.16825.
9. Veroustraete. F., Maiheu. B., Janssen. S., and Mensink. C., 2010: On the Application of OPAC in the Remote Sensing of Aerosols, Geophysical Research Abstracts, Vol. 12, EGU2010-14668-1, Flemish Institute for Technological Research, Spatial and Atmospheric Modeling Unit, Mol, Belgium.
10. Kim. D., M. Chin, H. Yu, T. F. Eck, A. Sinyuk, A. Smirnov, and B. N. Holben, 2011: Dust optical properties over North Africa and Arabian Peninsula derived from the AERONET dataset, www.atmos-chem-phys-discuss.net/11/20181/2011/ doi:10.5194/acpd-11-20181.
11. Khoshsima, M., Bidokhti, A. A., and Ahmadi, F., 2014: Variations of aerosol optical depth and Angstrom parameters at a suburban location in Iran during 2009–2010. J. Earth Syst. Sci. 123, No. 1, February 2014, pp. 187–199.
12. Gharibzadeha, M., Alamb, K., Abediniacd, Y., Bidokhtie, A. A., and Masoumia, A., 2017: Monthly and seasonal variations of aerosol optical properties and direct radiative forcing over Zanjan, Iran. Journal of Atmospheric and Solar-Terrestrial Physics, Volume 164, November 2017, pp 268-275.
13. Rezaei, M., Farajzadeh, M., Ghavidel, Y. and Alam, K., 2018: Spatio-temporal variability of aerosol characteristics in Iran using remotely sensed datasets. Pollution, 4(1): 53-67.
14. Al-Salihi, Ali. (2018). Characterization of aerosol type based on aerosol optical properties over Baghdad, Iraq. Arabian Journal of Geosciences. 11. 10.1007/s12517-018-3944-1.
15. Hess, M., Koepke, P., and Schult I., 1998: Optical Properties of Aerosols and Clouds: The Software Package OPAC. Bull. Amer. Meteor. Soc., 79, 831–844.
16. Gordon, J. F., 1970: Dynamic visibility. A conceptual review. AFGL-TR. 79-0257.