A study of atmospheric aerosol optical properties over Alexandria city- Egypt

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Abstract. Aerosols are minute particles suspended in the atmosphere. When these particles are sufficiently large, we notice their presence as they scatter and absorb sunlight. They scatter and absorb optical radiation depending upon their size distribution, refractive index and total atmospheric loading. Aerosol optical depth (AOD) was measured at Alexandria city (31° 16' N, 30° 01' E and 21 m above sea level) using hand-held microprocessor-based sun photometer “MICROTOPS II”. AOD is studied at five different wavelengths from 380 to 1020 nm during the period from Aug-2015 to Feb-2016. Precipitable water column (PWC) is estimated from the measurements of solar intensity at 936 and 1020 nm. Diurnal, monthly and seasonal variation of AOD and water vapor content was studied during the study period. The seasonal variation of AOD has high value (0.416) in summer and low value (0.176) in winter at wavelength of 380 nm. The changes in the PWC have been found to be correlated with changes in AOD. This is supported by the observed increase of AOD with relative humidity (RH) values.

1. Introduction
Aerosols play an important role in earth’s radiation budget, air quality and environmental health [1-3]. Aerosols are tiny particles in solid or liquid phase suspended in the air. They occur over a wide range extended from $10^{-2}$ μm to about $10^{2}$ μm; the size range 0.1-1 μm are most effective in attenuating sunlight [4]. There are two sources of aerosols; natural source and anthropogenic source. Natural source such as volcanic activity, windblown dust, sea spray, convective and general circulations produce regional-scale effects of modulating background aerosol, while the anthropogenic sources of aerosols are combustion, industrial activities, transport and mining to regional-scale differences in aerosol properties. One of the most important optical properties of aerosol used in radiative transfer calculation is aerosol optical depth (AOD). It is defined as the attenuation of direct solar radiative passing through the atmosphere by scattering and absorption due to aerosols [5]. The aim of this study is to measure AOD and PWC by using MICROTOPS II sunphotometer (Solar light co.) at Alexandria City. Probably the local aerosols are a mixture of aerosols originating from windblown dust, vehicular sea bubbles burst, as the region is a coastal and crowded with population as well as it is near from the desert.
2. Materials and method

2.1. Site description
This study was carried out at Alexandria city. Alexandria is a coastal city (31° 16’ N, 30° 01’ E and 21m above sea level) and it is an urban area. It has 40% of total industry in Egypt. It extends along the coast of the Mediterranean Sea in the north-central Egypt. It has a pleasant Mediterranean climate. August is the hottest month has an average temperature reaching 31°C, while January is the coldest month has an average temperature reaching to 18°C. The summer season is hot and the average of the humidity varies from 58.2 to 48.8%. The site of the study is an urban area, so it is very crowded and the pollution load is high compared with rural areas.

2.2. Methodology
MICROTOPS II is a five channel hand-held sunphotometer which is used for measuring AOD easily, accurately and dependably. The MICROTOPS II sunphotometer provides the aerosol optical thickness at the standard wavelengths 380, 440, 500, 936, and 1020 nm. It also measures direct solar irradiance at the five wavelengths and PWC at 936 and 1020 nm [6]. GPS Model Garmin (72H) was used. Accurate location parameters can be automatically transferred from the GPS receiver to the MICROTOPS II. MICROTOPS II works only when the sky is clear otherwise an error will occur, so clear days were chosen (no clouds or mist in the sky). The measurements were carried out one day per week during the study period (Aug-2015 to Feb-2016). The diurnal and monthly variations were calculated during the study period. Meteorological data (humidity and wind speed and direction) were downloaded from the internet.

3. Results and discussion
Measuring Aerosols distributed within a column of air from earth’s surface to the top of the atmosphere was made by MICROTOPS II which calculates the aerosol optical depth (AOD) values at each wavelength based on the channels, its extraterrestrial constant, atmospheric pressure (for Rayleigh scattering), time and location. Sun distance correction is automatically applied. All calculations of AOD are based on the Bouguer- Lambarert-Beer law at the following formula,

\[
\tau_{\lambda} = \left( \frac{\ln(V_{\lambda}) - \ln(V_{\lambda} \times SDCORR)}{M} \right) - \left( \frac{T_{R3}}{P_{o}} \right) \frac{P}{P_{o}}
\]

Where \(\lambda\) refers to the selected wavelength, \(\ln(V_{\lambda})\) refers to the AOD calibration constant of the selected wavelength, \(V_{\lambda}\) is the signal intensity at the selected wavelength in (mV), SDCORR is the mean Earth-sun distance correction, \(M\) is the optical air mass, \(T_{R3}\) is Rayleigh optical depth at the selected wavelength and \(P\) and \(P_{o}\) are the atmospheric pressure at the study region and sea level pressure in (mbar) respectively [6].

PWC is measured through two wavelengths, the first one is 936 nm which water absorption band and the second is 1020 nm which is no water absorption band. The following equation that measures PWC based on Bouguer- Lambarert- Beer law and it is measured in cm scale [7].

\[
W = \left( \frac{\ln V_{o(936)} - \ln V_{(936)} - T_{(936)} \times M}{K \times M^{b}} \right)^{1/b}
\]

Where \(K\) and \(b\) are constants numerically derived for the filter.

3.1. Diurnal variation
‘Figure 1’ shows the diurnal variation of aerosol optical depth at five different wavelengths (380, 440, 500, 936 and 1020 nm), while ‘Figure 2’ shows the diurnal variation of PWC at wavelengths 936 and 1020 nm during the study period.
The maximum value of AOD was at 10 am while the minimum value was 4 pm. This trend is consistently seen at all wavelengths. AOD values also show comparatively high values at 10 am, then a slight decrease, but the values increased again, this may be due to increasing of the temperature and the human activity as well. ‘Figure 2’ shows that the PWC along the day has variable values as it is very high at the morning (0.166 at 8 and 10 am) and very low at the afternoon (0.151 at 4 pm), this may be due to raise in the temperature, so water vapor evaporated.

3.2. Monthly Variation
Monthly values of AOD were calculated during the study period at mentioned wavelengths as shown in ‘Figure 3’. It can be seen that the highest values was at Aug-15 (0.416 at 380 nm) while the lowest values was at Jan-16 (0.176 at 380 nm). The trend was decreasing regularly till Jan-16. High values of AOD during the summer may be due to increasing of the heat of the surface of the earth, because of the increasing of the temperature, which makes evaporation to molecules and this molecules raise in the atmosphere and this, was observed during the high temperature periods. The lowest values of AOD were obtained in winter at Jan-16 and this may be due to cloud scavenging and rain wash out processes and decreasing the temperature and this ensures the previous interpretation.

‘Figure 4’ shows the monthly variation of precipitable water content for the study period. The highest value was at Aug-15 (2.23 cm), while the lowest value was Feb-15 (1.12 cm). Trend of precipitable water content is as well as the AOD trend because both are related to digital voltage (V) and its calibration constant ln(Vo). Generally the precipitable water content values are high in summer
and low in winter this is may be due to hygroscopic growth of AOD and the humidity is very high in summer which lets some liquid particles suspended in the atmosphere.

3.3. AOD Spectral dependence and Ångstrom parameters

AOD spectral dependence was studied during the study period at the five wavelengths as shown in ‘Figure 5’. This study observed that AOD values are inversely proportional with the wavelength. There is an enhancement in AOD values between the two wavelengths; 440 and 500 nm; this may be due to water vapor interference, clouds or sunlight [8].

![Figure 5. AOD Spectral dependence for the study period](image)

Ångstrom parameters; i.e. wavelength exponent $\alpha$ and turbidity coefficient $\beta$, were calculated as shown in ‘Figure 6’. In this study $\alpha$ are less than 2.0 along the study period, so the aerosol is coarse along this period but differs from month to another. Turbidity coefficient ($\beta$) values are varied between 0.1 and 0.2 during Aug-2015 to Nov-2015, so the atmosphere is not clear during this period, but $\beta$ values are less than 0.1 during the period from Dec-15 to Feb-16, so the atmosphere is clear as expected because of rains, this interpretation is due to standard Ångstrom parameters [9].

![Figure 6. Ångstrom parameters; wavelength exponent and turbidity coefficient during the study period](image)

3.4. Meteorological conditions

It was observed from this study that all meteorological conditions affect the AOD values and PWC values. Temperature, humidity and wind speed and direction is directly proportional, but the atmospheric pressure is inversely proportional with the value of AOD and PWC. Meteorological data; humidity, wind speed and direction were collected from the internet [10], but the temperature and the atmospheric pressure were collected by the instrument itself.

4. Conclusion

Aerosols are tiny particles suspended in the air in solid or liquid phase. Aerosol values are high during the summer months, but AOD values are low during the winter and the post monsoon rains due to rain wash out. PWC values tend to follow the AOD values, as it is high during the summer due to raising of the humidity and low during the winter. Meteorological conditions; temperature, pressure, humidity and/or wind speed and direction, have an effect on the values of AOD and PWC. There is an enhancement in the spectral dependence between the two wavelengths; 400 and 500nm because of interference with water vapor, clouds or sunlight according to NASA, earth observatory.
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