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Optically Classified Aerosol Properties for Mersin - Erdemli

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Abstract **-** Planetary studies have been focused on identifying the chemical components of the earth's atmosphere for over three centuries. Nitrogen, oxygen, carbon dioxide, and noble gases are the major, and trace species are the minor chemicals of the planet earth's atmosphere. They might be found in solid spheroids, liquid droplets, or gases. Whether the specie is an aerosol or a trace gas, many of them are short-lived, necessitating prompt investigation methods to define their spatial and temporal abundance. Remote sensing technologies are robust and prompt solution methods in atmospheric chemistry and physics. Satellite onboard and in-situ sensors provide continuous and human-independent observations even in remote sites. These remotely sensed near real-time data enable scientists to study trends, climatologies, long-range transport of pollutants, and air quality. This study implements a robust aerosol classification method for IMS-METU-Erdemli AERONET station measurements. The station is significant in Levantine Basin and serves a mixture of marine, dust, and anthropogenic aerosols. Results reveal that the ambient air of Erdemli has high pollution levels primarily composed of spheroid particles. Furthermore, these spheroids are more prone to contaminate clouds in smaller sizes, while bigger sizes show the hygroscopicity of the particles.

Keywords**:** AERONET, Aerosol Optical Thickness, Climatology, The Eastern Mediterranean Basin, The Levantine Basin

1. Introduction

Since the eighteenth century, planetary studies have been focused on identifying the chemical components of the earth's atmosphere. The atmosphere has major and minor features. Nitrogen, oxygen, carbon dioxide, and noble gases are the major, and trace species are the minor chemicals. Trace species might be found in the form of solid spheroids, liquid droplets, or gases. Whether the specie is an aerosol or a trace gas, a significant proportion of them are short-lived, necessitating prompt investigation methods to define their spatial and temporal abundance.

Together with atmospheric trace gases, determining the variability of aerosols are crucial in better understanding air pollution, radiative forcing, and climate change. Conventional and highly reliable measurement techniques are mainly based on collecting filter samples and analyzing them in laboratory conditions. Moreover, if high temporal coverage is desired on a single point, in-situ measurements are more effective with the elaborately chosen station location and properly running instruments. When the principal investigator meets the station representation circumstances, temporal coverage will be satisfied for the data collection. But under human-dependent conditions, mistakes are mostly a foregone conclusion, reveals to the loss of time and funding and bringing the need for fully automated systems into the light. Thus, it would be easier to collect data from remote sites.

Remote sensing technology has entered a new era with earth-orbiting satellites within the past six decades and reached the highest spatial coverage in a limited time window, especially in atmospheric studies. Radiometers, radio detection and ranging (radar)s, and light detection and ranging (lidar)s are critical instruments for quantifying atmospheric constituents remotely. These specific payloads can be employed onboard a satellite or established in an in-situ site according to scientific needs. If high spatial coverage is in question, satellites are the answer, but if a high temporal resolution is needed, in-situ remote sensors meet the subject. They can provide continuous data in a near real-time degree. Though the initial investment costs are pretty high, so is the life span of the instruments. Remotely sensed continuous data enable scientists to study trends, climatologies, long-range transport of pollutants, and air quality.

One of the most used reliable remote sensors is the radiometer; the so-called sunphotometer was first introduced by Voltz [1]. Since then, the technology has been developed from hand-held analogous to fully automated. There are several radiometers have been run by well-established networks around the world. The most reliable ones are Global Atmosphere

Watch Precision Filter Radiometer Network (GAW-PFR), Aerosol Robotic Network (AERONET), SKYNET, and NOAA Federated Aerosol Network (NFAN). These networks offer standardized and quality-assured data on aerosol monitoring and characterization. With over 1,700 monitoring stations and full-automated CIMEL sun-sky radiometers, AERONET (2022) is the most globally widespread network among the others. Sky measurements are performed at 440 nm, 670 nm, 870 nm, and 1020 nm, while direct sun measurements are at eight standard channels between 340 nm and 1020 nm. Some of the leading products of the specified direct sun measurements are precipitable water (pw), Aerosol Optical Thickness (AOT), and Angstrom exponent (α), and sky measurements are spectral irradiance and sky radiance inversions [2]. Spectral irradiance and sky radiance inversions are commonly used in radiative forcing calculations, whereas water precipitation is the essential parameter. AOT is a measure of columnar aerosol concentration from ground level up to the top of the atmosphere (TOA). Angstrom exponent is the spectral dependence of measured AOT, introduced by Angstrom in 1929 [10]. Both AOT and the Angstrom exponent are crucial in determining size distributions [3], variability [4], baseline concentrations [5], and classification of aerosols [6],[7]. As well as the direct usage of these parameters is already helpful, but also it is possible to derive additional optical parameters and perform more complex analyses.

Turkey has only one active AERONET station: The Institute of Marine Sciences - Middle East Technical University (IMS-METU) - Erdemli, serving data since 1999. Besides the data served, the location (N - E) is so substantial that it belongs to the Levantine Basin in the Eastern Mediterranean Basin. This region has been threatened by global warming and climate change. Moreover, it has been surrounded by deserts, marine environments, and urban territories [8].

A robust aerosol classification method is implemented for the IMS-METU-Erdemli station data. This relatively simple yet sophisticated method provides information on aerosol sphericity and cloud contamination in the ambient atmosphere [6],[7]. The Data and Methodology section gives a detailed explanation of the method. Classification results are presented in the Results and Discussion section. The final summary, recommendations, and analyses planned to be conducted are highlighted in the Conclusions section.

2. Data & Methodology

AERONET is a federated radiometer network that offers a stable and trusted ground-based aerosol monitoring and data archiving system [2]. Level 2, Version 3 quality assured, cloud screened, and pre and post-field calibrated direct sun measurement data for Mersin, Erdemli is gathered from the AERONET website [9]. IMS-METU-Erdemli AERONET station has been providing trusted data since 1999. The optical classification method offered by Gobbi et al. [7] is implemented to the data according to the following steps:

- All measurement points for α (440 nm, 675 nm), AOT (870 nm), and AOT (675 nm) are gathered from the AERONET data archive. 440 nm and 870 nm spectral bands are the most measured wavelengths in all AERONET stations. 675 nm indicates urban, marine, and dust mixture aerosols.
- α (675 nm, 870 nm) is calculated for all points according to Eq 1.
- The curvature of the aerosols ($\delta\alpha$) is then calculated according to Eq 2.
- All AOT (675 nm) points are classified to their pollution ranges: 0.3>AOT>0.15, 0.4>AOT>0.3, 0.7>AOT>0.4, 1.0>AOT>0.7, 1.5>AOT>1.0, 2.0>AOT>1.5, 3.0>AOT>2.0, and AOT>3.0, respectively.
- Graphical gridlines are determined according to the Mie calculations with the refractive index for the mixture aerosols (m=1.4-0.001i). The percentages indicate aerosol growth with cloud contamination and other chemical mechanisms.
- Derived data is depicted on the graph as the Angstrom difference ($\delta\alpha$) to the Angstrom exponent α (440, 875).

$$\alpha(675{,}870) = -\frac{ln({^{AOT870}}/_{AOTA675})}{ln({^{870}}/_{675})} \tag{1}$$

$$\delta\alpha = (440{,}870) - (675{,}870) \tag{2}$$

3. Results & Discussion

Optically classified 18-year aerosol climatology results for Mersin – Erdemli are presented in this section. Data availability of AOT and corresponding Angstrom exponent measurements are given in Table 1. Except for 2002, the sunphotometer has been up and running since 1999. It can be seen from the table that the data availability varies from year to year. The reason underlying the variance is that the instrument is a sun photometer. It is a passive remote sensor that utilizes sunlight and conducts the measurements under clear sky conditions and thin cloud presence in the atmosphere. These differences are due to the technical nature of the instrument itself rather than a failure.

Table 1: Annual data availability of Angstrom exponent and AOT measurements.

Year	Number of Measurements	Year	Number of Measurements
1999	813	**2008**	11,030
2000	8,259	**2009**	10,112
2001	3,404	**2010**	3,975
2002	NaN	**2011**	6,602
2003	6,454	**2012**	557
2004	7,223	**2013**	6,138
2005	7,983	**2014**	4,343
2006	1,335	**2015**	1,693
2007	3,862	**2016**	7,241

Pollution levels and their ratios out of the total AOT (675 nm) measurements are depicted in Figure 1. Although the columnar thickness of the aerosols is not a measure of size distributions, pollution levels can instead be used to predict the type of contamination of the ambient atmosphere. These results show that the atmosphere is far from clear sky conditions on observation days. AOT level of 0.3 indicates high urban pollution. From 0.2 and overvalues, one can think that there are bigger particles that can mimic a source region of dust and marine aerosols or that the station's location is closer to those sources.

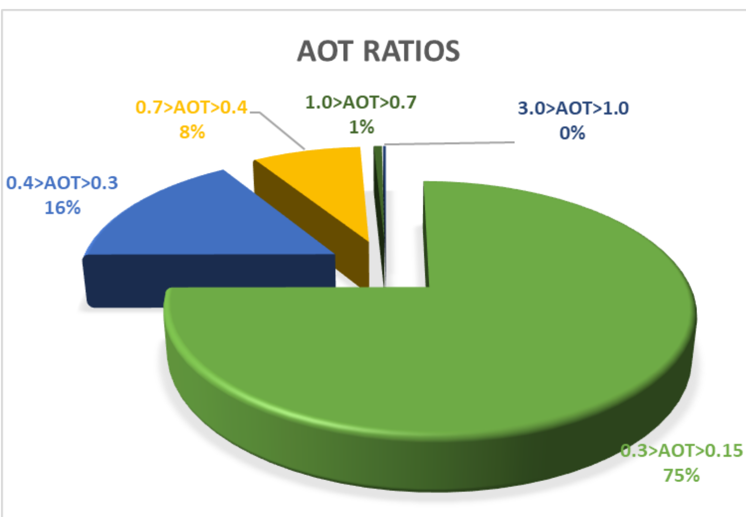

Fig. 1: 18 – year pollution level classified ratios out of the total number of AOT measurements (1999 – 2016).

The main optically classified 18-year climatology results are given in Figure 2; as the Angstrom difference increases and the Angstrom exponent decreases, aerosol size decreases. It is clear from the figure that the bulk pollution up to the 0.3 AOT level is a mixture of both fine and coarse mode particles. The coarse mode has higher ratios and is prone to behave as 90% hygroscopic. As the curvature of the particle increases, hygroscopicity potential drops dramatically. However, spheroids emerge in the ambient air if such mechanical or chemical processes corrupt the particles' curvature. Furthermore, they have more hygroscopicity. The region with larger AOT (from 0.7 to 3) and Angstrom exponent values between 0 and 0.3 and Angstrom difference increases and negative to lightly positive indicates the presence of dust in the region.

The higher pollution levels above 0.3 AOT are primarily composed of spheroids. If these spheroids are smaller, as indicated by a yellow circle on the graph, they are more prone to contaminate clouds and reveal scavenging. If the scavenging mechanism does not occur in the air, growth spheroids can be found in the atmosphere.

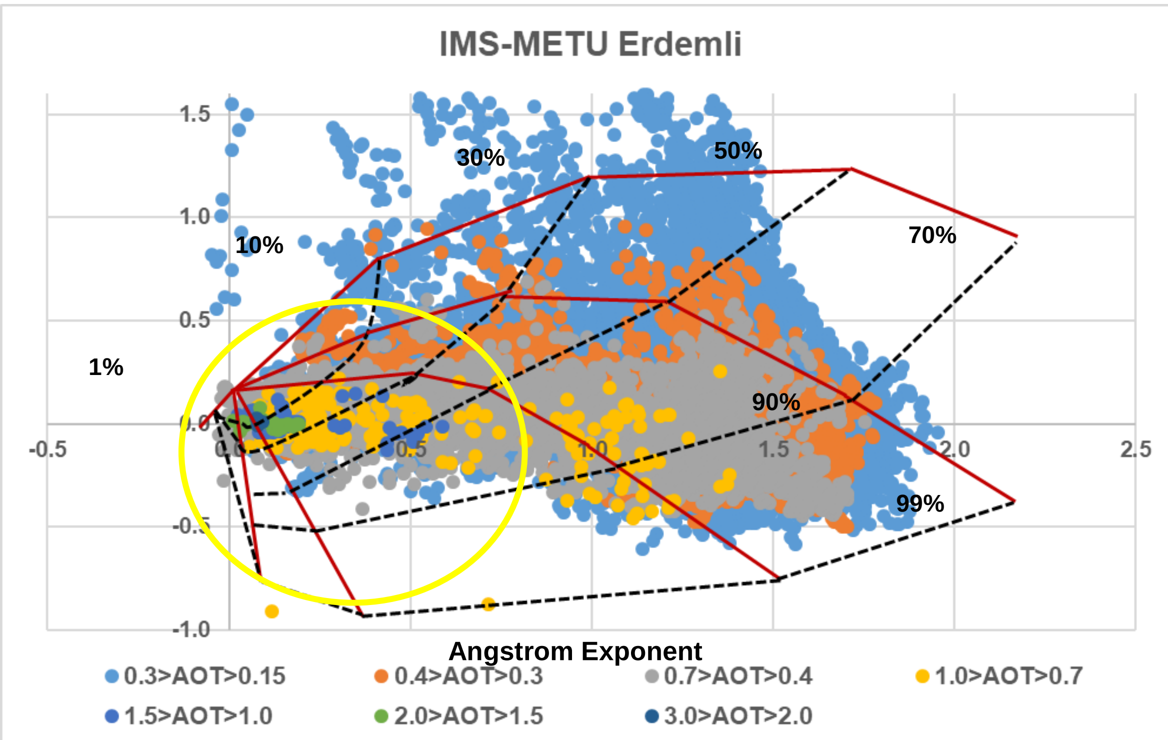

Fig. 2: Angstrom exponent difference (δα) as a function of the Angstrom exponent (α, 440 – 870 nm) and color-coded AOT values for IMS – METU – Erdemli AERONET station (1999 – 2016).

4. Conclusion

Mersin – Erdemli coastal city is located in the Levantine region of the Eastern Mediterranean Basin. Also, the city is in the neighborhoods of desert source areas, urban territories, and big harbors. These circumstances reveal aerosol-contaminated ambient air in most of the observation period. It can be attributed to anthropogenic activities, the local marine environment, and long-range transported desert dust. One should remember that the long-range transported particles are natural; they are still pollutants and can be contaminated with anthropogenic ones while traveling from the source. This graphical method enables a complete picture of bulk aerosol load over the city. Moreover, the results compose a climatology with combined size, sphericity, and hygroscopicity information of aerosols. The following steps should be conducting flow climatology and source apportionment analyses for this data to constitute a more complete and and helpful climatology.

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