KYRGYZ NATIONAL UNIVERSITY
«Issyk-Kul» Research Station

Retrieval of Aerosol Optical Parameters from the Data of CIMEL Sun photometer Measurements at the «Issyk-Kul» Research Station

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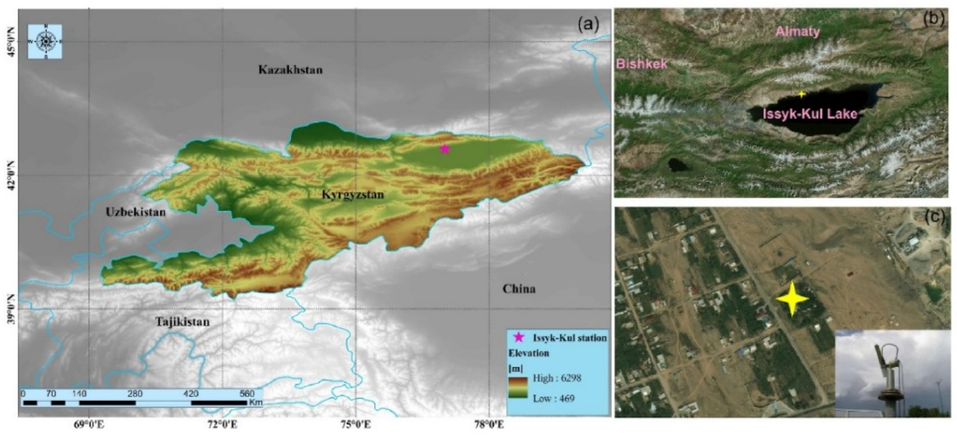
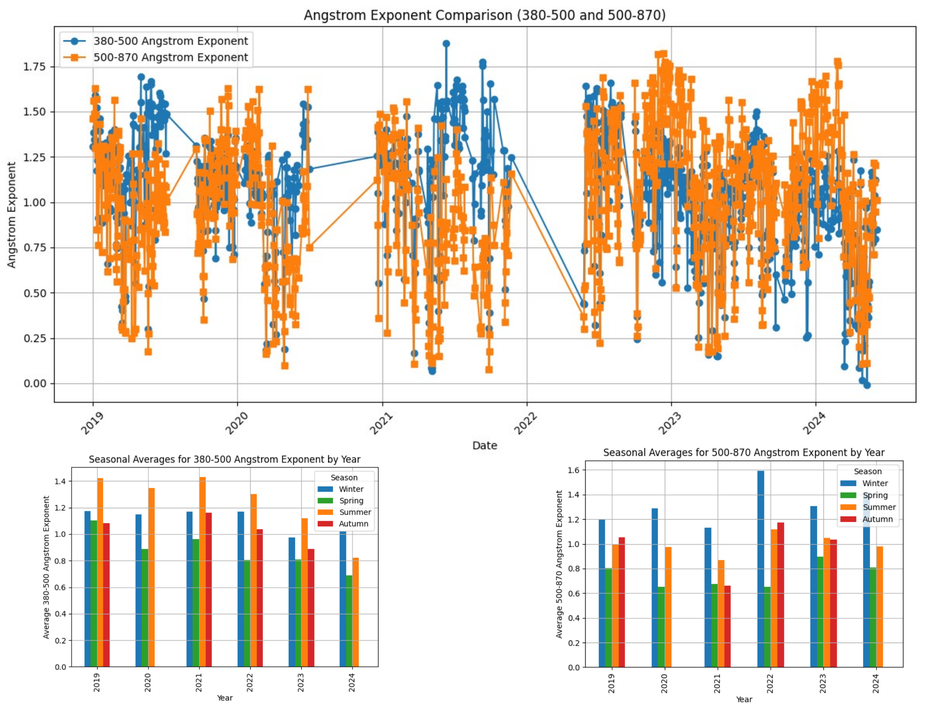
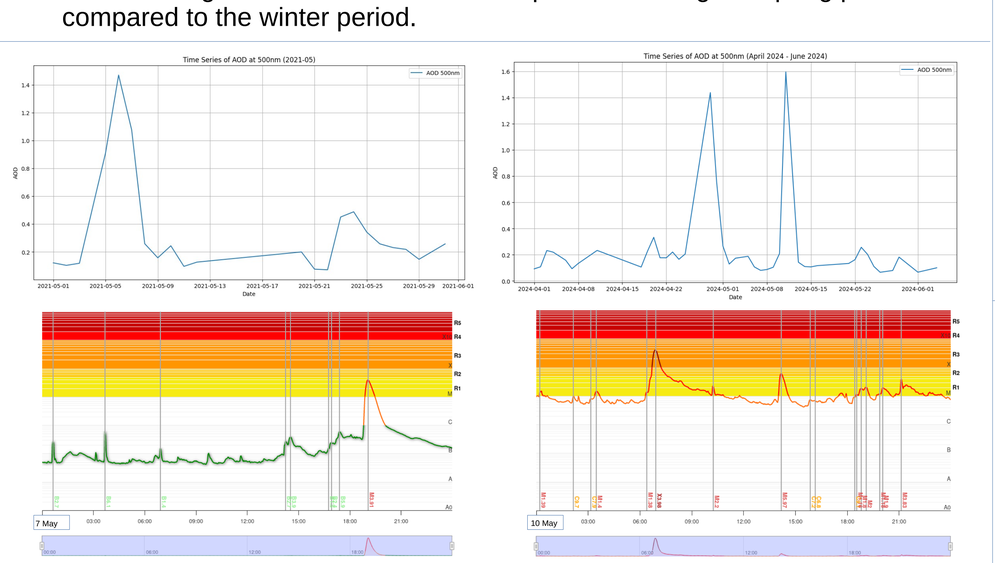
Atmospheric aerosols play a pivotal role in modifying climate processes, air quality, and public health by affecting radiative forcing, cloud formation, and precipitation. This study presents a comprehensive analysis of aerosol optical depth (AOD) and the Angstrom exponent (AE) obtained from the CIMEL sun photometer at the Issyk-Kul Research Station in Kyrgyzstan, under the NASA AERONET program. Utilizing high-quality level 2 and level 1.5 data collected between 2019 and 2024, we examined the temporal and seasonal variations in aerosol characteristics.



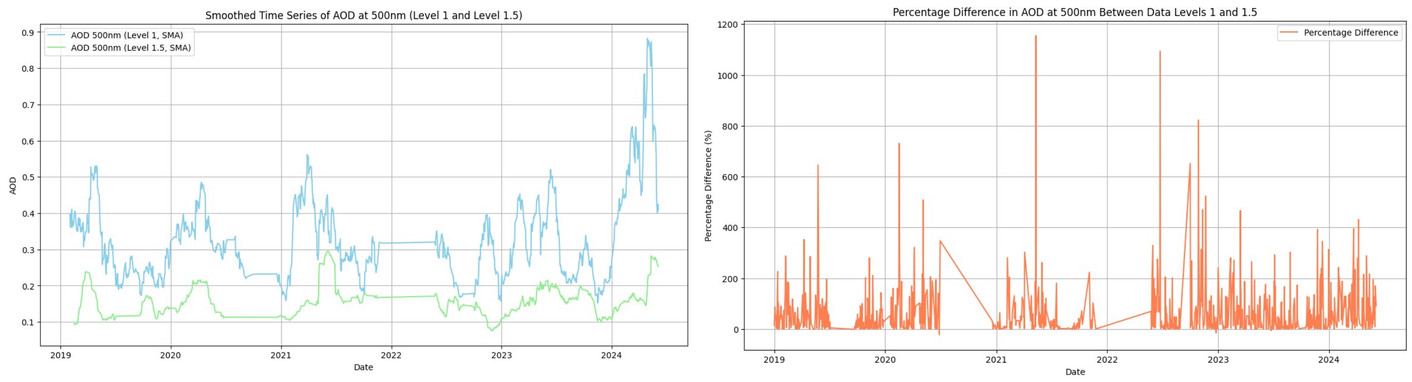
The Issyk-Kul Research Station is located on the shores of Lake Issyk-Kul in Kyrgyzstan, between latitudes 42.6° N and longitudes 77.0° E, at an elevation of 1650 meters above sea level. Issyk-Kul is surrounded by two mountain ranges: the Kungei Ala-Too to the north and the Terskei Ala-Too to the south, creating complex geophysical conditions.
The Issyk-Kul Station was established in August 2007 as part of the NASA AERONET (AErosol RObotic NETwork) program to study the properties of columnar aerosols in the background atmosphere of Central Asia. The station is equipped with a CIMEL sun photometer, which measures direct solar radiation in eight channels ranging from 340 to 1020 nm and sky radiation in four channels ranging from 440 to 1020 nm.



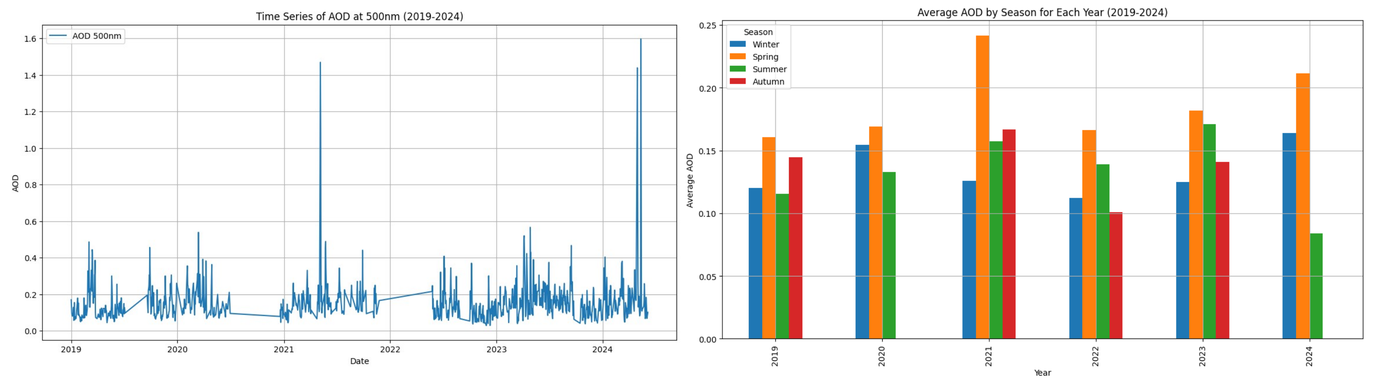
The average values of the Angstrom exponent, calculated for each season and year, exhibit significant variability between winter and summer months. During the winter period, the average Angstrom exponent in the 380-500 nm range was 1.2, in spring it was 1.4, in summer 1.3, and in autumn 1.1. In the 500-870 nm range, the average values were 1.1 in winter, 1.3 in spring, 1.2 in summer, and 1.0 in autumn.
These data indicate seasonal variability in aerosol particle sizes, with an increase in smaller particles during the spring and summer. The difference between winter and spring periods for the 380-500 nm range is approximately 16.7% (1.4 in spring versus 1.2 in winter), and for the 500-870 nm range, it is approximately 18.2% (1.3 in spring versus 1.1 in winter). These percentages indicate a significant increase in smaller particles during the spring period compared to the winter period.



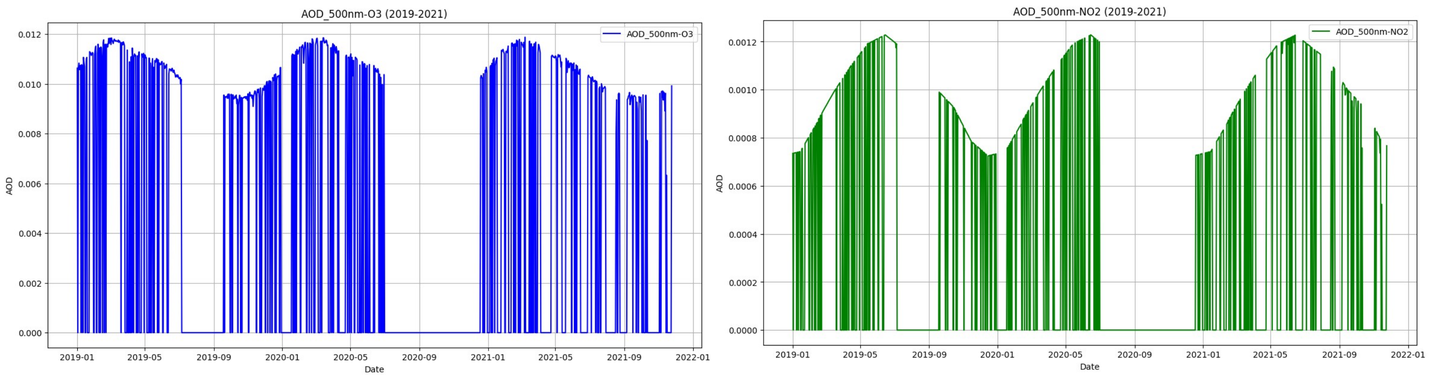
At a wavelength of 500 nm, significant seasonal fluctuations were observed in AOD values for the year 2021. AOD values ranged from 0.1 to 1.5, with peak values occurring in the spring and summer months. Similar seasonal fluctuations were observed in the AOD time series graph for 2024. The analyzed data revealed days with extremely high AOD values, reaching 1.4 and 1.5. In 2021, these extreme AOD values exceeded the average summer values by 55.6% and 66.7%, respectively, while in 2024, they were higher by 75% and 87.5%. The peak AOD values corresponded to periods of active solar flares.



In the time series graph, it is evident that the data from levels 1 and 1.5 exhibit similar trends in AOD variations, with some differences in amplitude. The average AOD values at level 1 ranged from 0.05 to 0.25, while at level 1.5, they ranged from 0.04 to 0.22. The highest values were observed in the spring and summer months, corresponding to periods of increased dust storm activity and anthropogenic emissions, with peak AOD values occurring in April and August.
The average AOD values calculated for each season show significant variability between winter and summer months. During the winter period, the average AOD was 0.08 (level 1) and 0.07 (level 1.5). In the spring, these values were 0.15 and 0.13, respectively; in the summer, 0.18 and 0.16; and in the autumn, 0.12 and 0.11. These results are consistent with previous studies, which noted that the highest AOD values are observed in the spring and summer due to increased dust content and other natural aerosols.

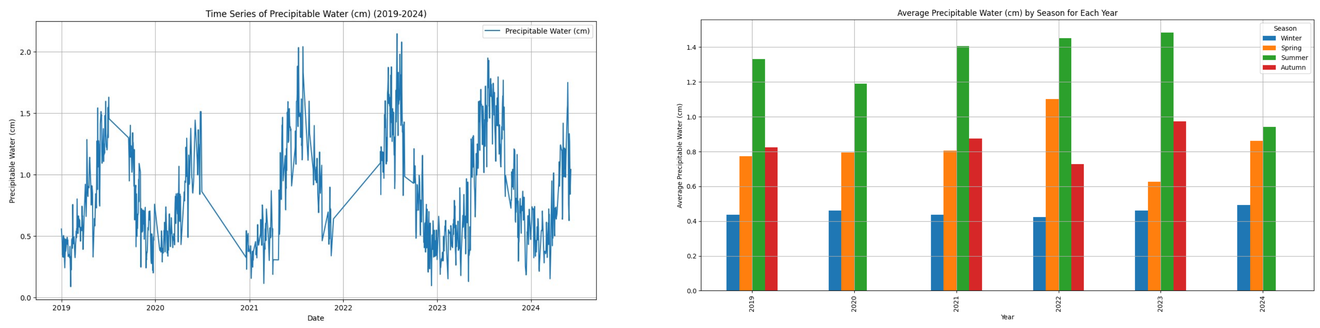


AOD exhibits significant seasonal and interannual variations. The average AOD values ranged from 0.05 to 0.25, with the highest values observed in the spring and summer months, corresponding to periods of increased dust storm activity and anthropogenic emissions. Peak AOD values were recorded in April and August.
The average AOD values calculated for each season and year show significant variability between winter and summer months. During the winter period, the average AOD was 0.08, in spring it was 0.15, in summer 0.18, and in autumn 0.12.
In spring 2021, the average AOD values were 10% higher compared to spring 2020 (0.16 versus 0.14). The summer of 2022 saw the highest AOD values of the entire study period, reaching 0.20, which is 11% higher than the summer of 2021 (0.18). In autumn 2023, the AOD was 0.13, which is 8% higher compared to autumn 2022 (0.12). In winter 2024, the average AOD values decreased to 0.07, which is 12.5% lower than in winter 2023 (0.08).



At the beginning of the period, in May 2019, AOD values were approximately 0.05. In the subsequent months, AOD values increased, reaching a peak of around 0.15 in August 2019. During the winter months, AOD values decreased back to 0.05, then increased again in the spring and summer of 2020, reaching 0.12 in July 2020. Thus, the changes in AOD between the winter and summer months amounted to approximately 200% (from 0.05 to 0.15).

For nitrogen dioxide (NO_2) during the period from 2019 to 2021, significant fluctuations in AOD values were also observed. In May 2019, AOD values were approximately 0.04, gradually increasing to 0.1 by July 2019, representing a growth of 150%. During the winter of 2019-2020, AOD values decreased to 0.03, then increased again in the spring and summer of 2020, reaching 0.09 in June 2020. Similar trends were observed in 2021, with peak values around 0.08 in June.



The time series graph of Precipitable Water (PW) from 2019 to 2024 shows significant seasonal fluctuations. PW values range from 0.5 to 5 cm, with peak values observed during the summer months. During the winter months (December, January, February), average PW values are around 0.7 cm. In the spring months (March, April, May), PW values increase to 2 cm. In the summer months (June, July, August), PW values reach their maximum, averaging around 4.5 cm. In autumn (September, October, November), PW values decrease to 2.5 cm.

The investigation of aerosol optical depth (AOD) and other related parameters from 2019 to 2024 revealed a slight increase in AOD over this period, with the lowest values observed in 2020. Maximum AOD values were recorded during the summer months, while minimum values were observed in the winter. This seasonal variability is attributed to changes in aerosol concentrations. These findings highlight the importance of accounting for seasonal factors in the analysis of atmospheric aerosols and their impact on climate processes and air quality.