Investigations on aerosol characteristics and trends over China from MODIS and OMI satellite data: Spatial and temporal distributions

Farong Deng,*, Kang Hu, Raghavendra Kumar Kanike, Na Kang

Key Laboratory for Aerosol-Cloud-Precipitation of China Meteorological Administration, School of Atmospheric Physics, Nanjing University of Information Science and Technology, Nanjing 210044, Jiangsu, China.

Abstract

With the rapid development of China's economy and high rate of industrialization, environmental pollution has become a major challenge for the country. 16 years of data (2000–2015) retrieved from the MODerate resolution Imaging Spectroradiometer (MODIS) and Ozone Monitoring Instrument (OMI) sensors was used to investigate aerosol optical depth (AOD550), Ångström exponent (AE470-660) and absorption aerosol Index (AAI). The spatial distribution of annual mean AOD550, AE470-660, and AAI were noticed to be high over economically and industrialized regions of eastern, southern and northeastern regions of China; while low aerosol loadings were located over rural and less developed areas of western and northeastern China. High AE values were characterized with the abundance of fine-mode particles and vice-versa; likely attributed to large anthropogenic activities, biomass burning and changes in meteorology. On the seasonal scale, AOD values were found to be high during spring followed by summer and autumn seasons, and low during the winter. Annual and seasonal spatial trends revealed decreasing trend in AOD over most regions of China, except in the southwest of China which showed positive increasing trends. Significant increasing trends were noted in AAI for all the seasons, particularly during autumn and winter, resulted in large amount of absorbing type aerosols from biomass burning and desert dust. Lastly, single peak distribution of frequencies of occurrences was characterized in AOD across all seasons.

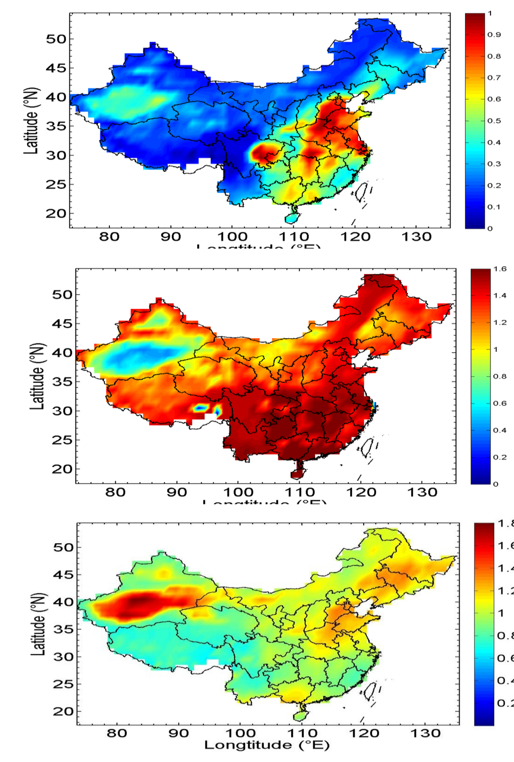
Introduction

Aerosols consist of solid or liquid particles suspended in the atmosphere with a typical radius ranging from 0.001 to 100 μm. They have significant and detrimental effects on human, visibility, climate and air quality. They decrease visibility and may lead to unsafe conditions for transportation. Aerosols have been described as the biggest source of uncertainty in climate change modeling and assessment. They affect climate directly by backscattering and absorbing both incoming solar radiation and outgoing terrestrial radiation; indirectly by modifying cloud quantity, lifetime, and other properties changing the Earth leaving radiation. Absorption of radiant energy by aerosols leads to heating of the troposphere and cooling of the surface, which can change the relative humidity and atmospheric stability, thereby, influencing cloud formation and precipitation. Consequently, aerosols can influence land surface processes, global surface temperature, climate, and the hydrological cycle and ecosystems.

Objective, Study area and method

Aerosols over China distribute distinctly over time and space because the type and magnitude of the aerosol sources vary greatly with regions. The spatiotemporal analysis of different aerosol optical parameters and their statistical trends were carried out over the entire mainland of China. However, because the region has a very large area with complex topography and aerosol source heterogeneity, we also focused on its eight provincial divisions. The main objective of this work is to investigate the spatial-temporal variability and trends of AOD, AE, and AAI using the recent Collection 6 (C006) remotely sensed satellite data retrieved from the MODIS and OMI sensors during 2002-2016. The C006 DT expected error is $\pm(0.15\times AOD+0.05)$ over land and $+(0.1\times AOD+0.04)$, $-(0.1\times AOD+0.02)$ over sea relative to the AERONET AOD (Levy et al. 2013; de Leeuw et al., 2017). The C006 DB expected error is $\approx\pm(0.2\times AOD+0.03)$ relative to the MODIS AOD (Hsu et al. 2013; Sayer et al. 2015).

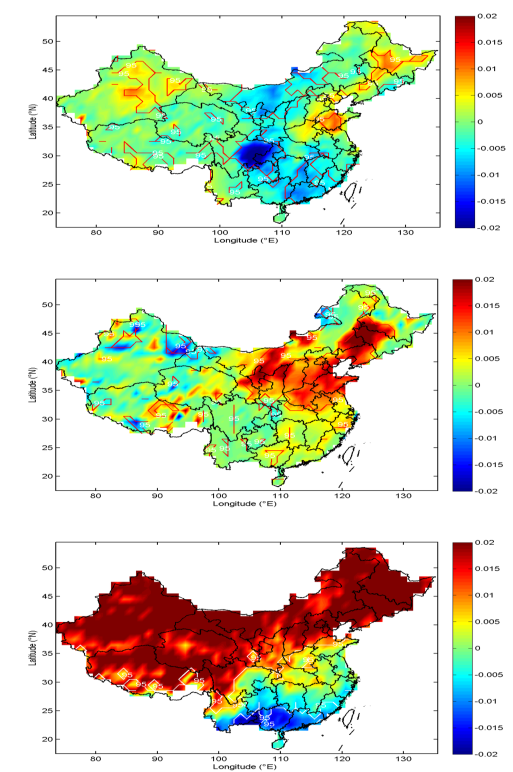
Variations of AOD, AE and AAI in China



Spatial climatology of annual mean a AOD at 550 nm, b AE at 470-660 nm, and c AAI observed over mainland China based on daily C006 combined (DT and DB) MODIS Aqua and OMI satellite products during the study period. The magnitude of color scale is presented in the color bar to the right of the map. Areas for which no data are available are shown as white.

High AOD centers (>0.8) were located over north China, east China, central (Henan province) and southwestern (Sichuan basin) provincial divisions of China. The areas with the lowest AOD (< 0.2) were mainly located in the west (Tibet region), southwest (Sichuan, Yunnan provinces), northeastern Inner Mongolia and northern Heilongjiang. It is depicted that most regions in China were characterized by high values of AE (>1.0), except the west, north, and northwest parts of China. Very high values of AAI (>1.4) signifying dominance of absorbing dust aerosols over the dust dominant regions of west China (around Xinjiang province), north (Inner Mongolia Autonomous region and Hebei province), central (Henan province), northeast (Heilongjiang, Jilin, Liaoning provinces) and east (Dongbei province) regions of China.

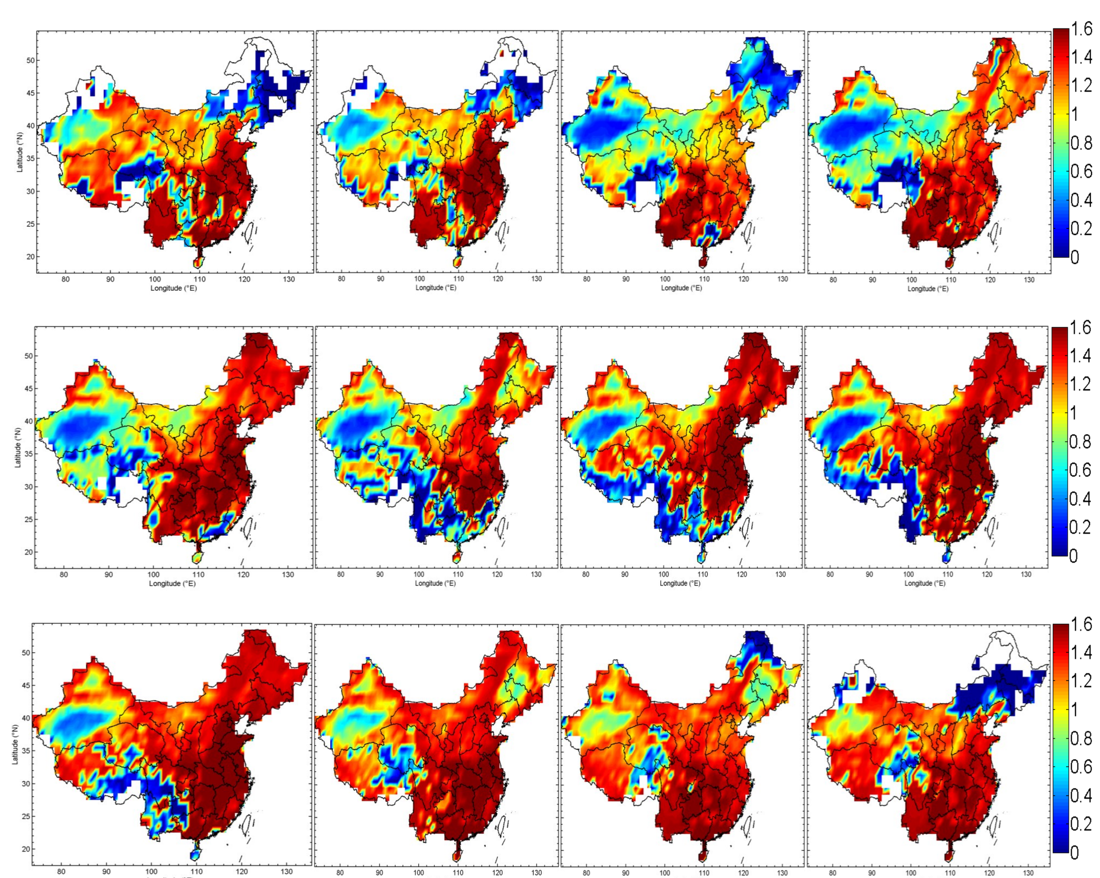
Trend analysis of AOD, AE and AAI

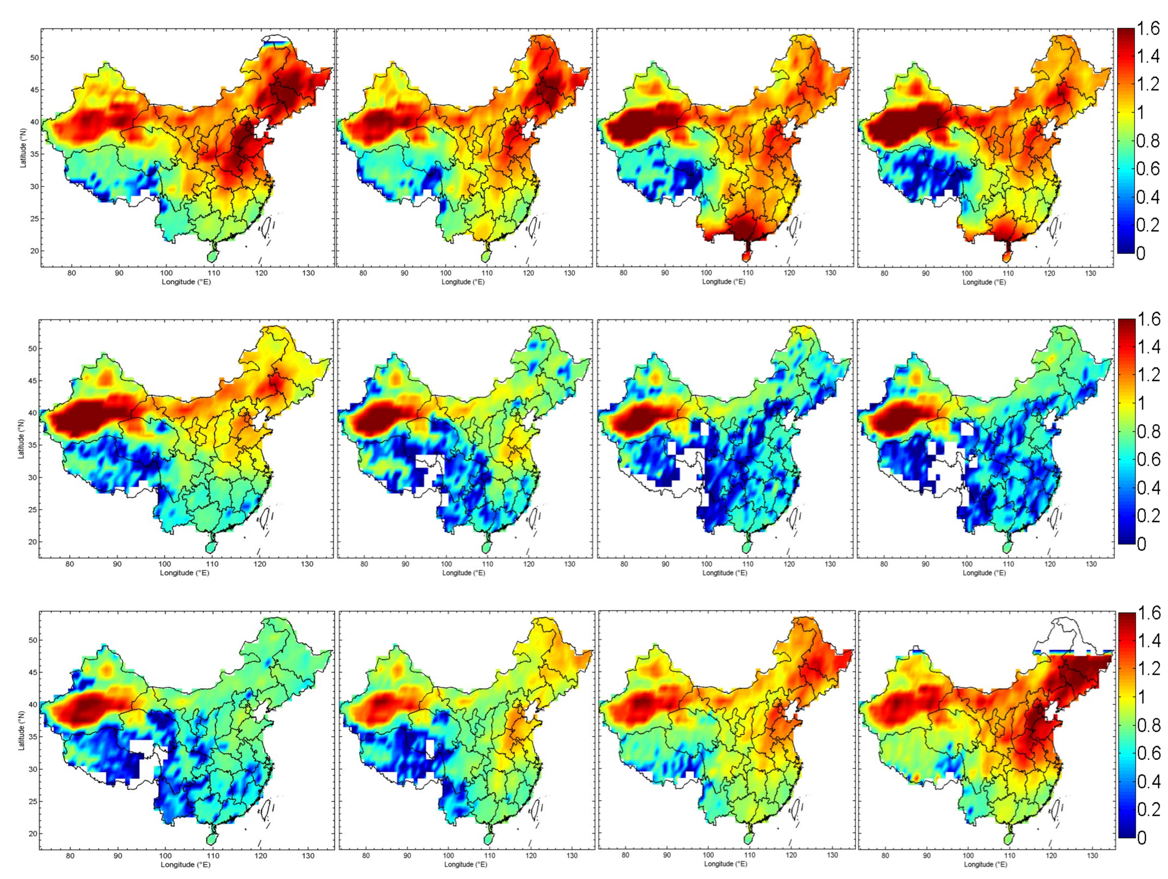


The annual mean spatial trends (AOD first, AE second, AAI third) observed during the study period. The significance test is conducted to the computed trends and represented with solid red and white (bottom panel only) lines evaluated at 95% confidence level.

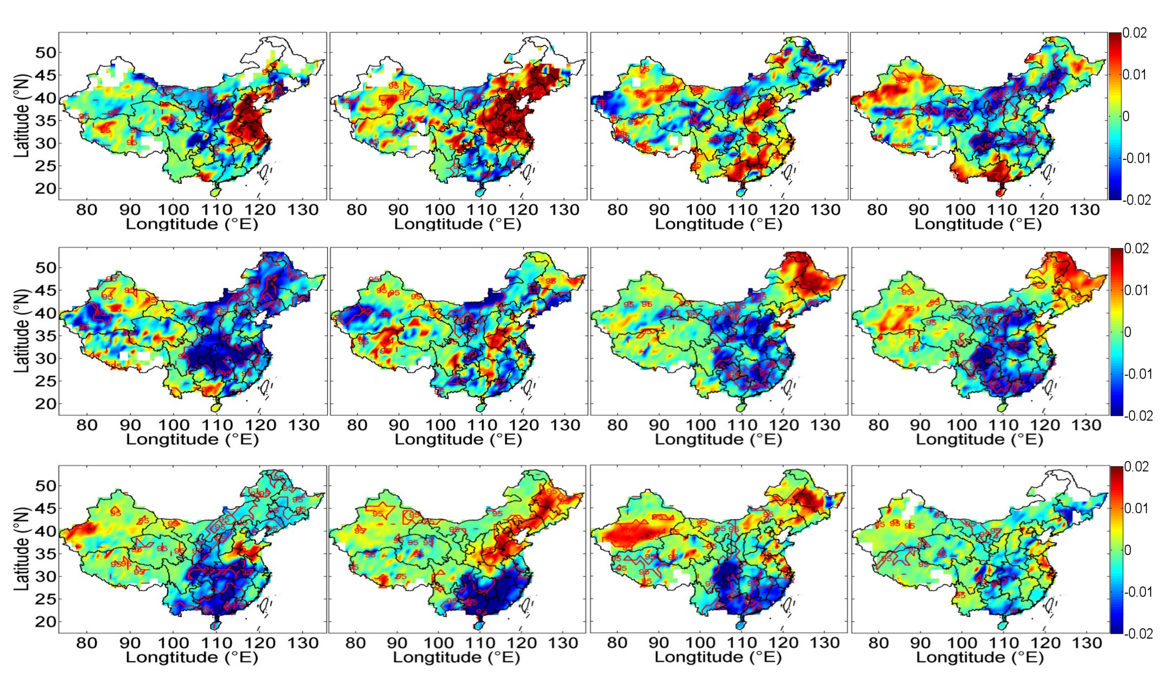
An overall decrease in AOD trends was observed, except in some regions over central, eastern, northeastern, and western parts of China which showed positive trends (~0.005 per year). The highest positive AE trends (>0.01) were depicted over the western, northwestern, northern, northeastern, and upper portions of Central and East China, attributing to the dominance of fine-mode particles. However, decreasing (negative slope values) AE470–660 trends were found in most regions across China with higher values(< −0.01) found in the west of China ascribed to an increase in the coarse-mode dust particles emitted from the desert zones. The increasing positive trends in AAI (corresponding to negative trends in AE) signify increased UV-absorbing aerosols mainly coarse-mode dust aerosols emitted in the northern and western areas of China.

Monthly AE and AAI values



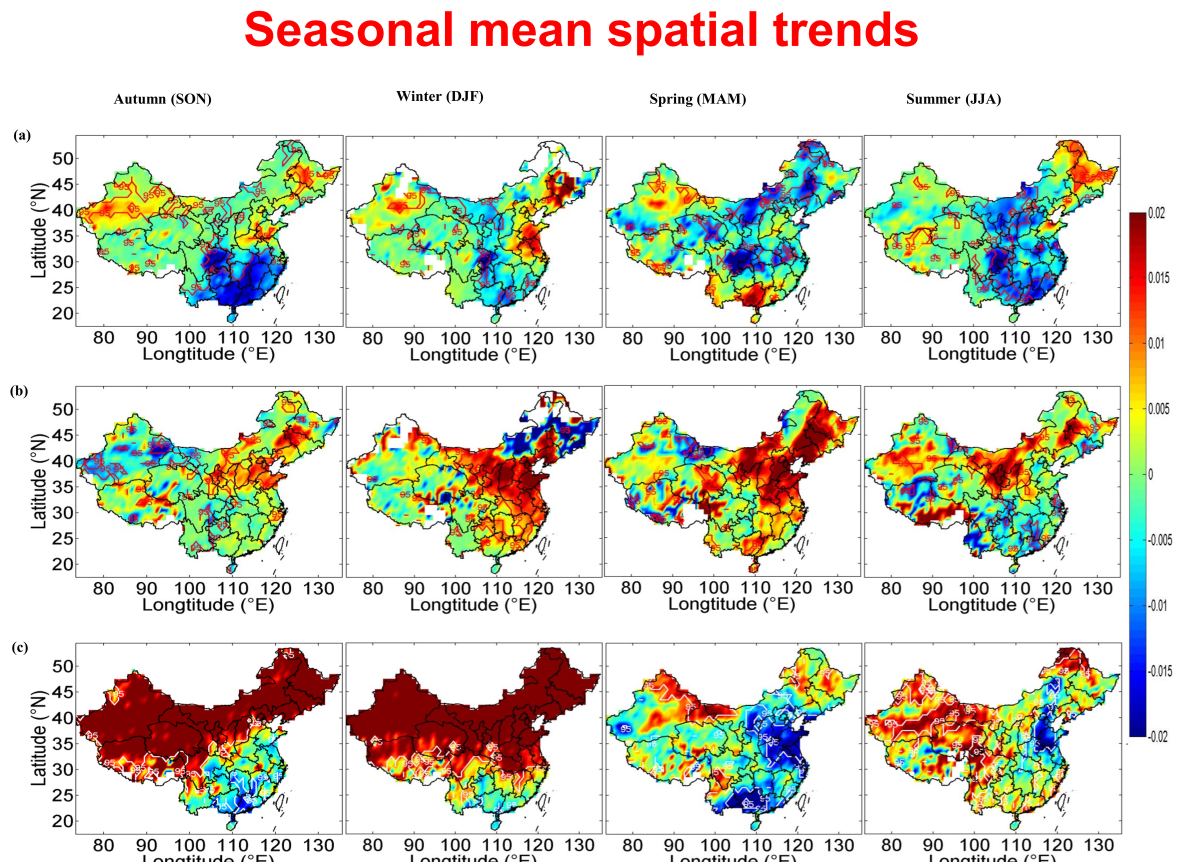


Monthly mean spatial trends



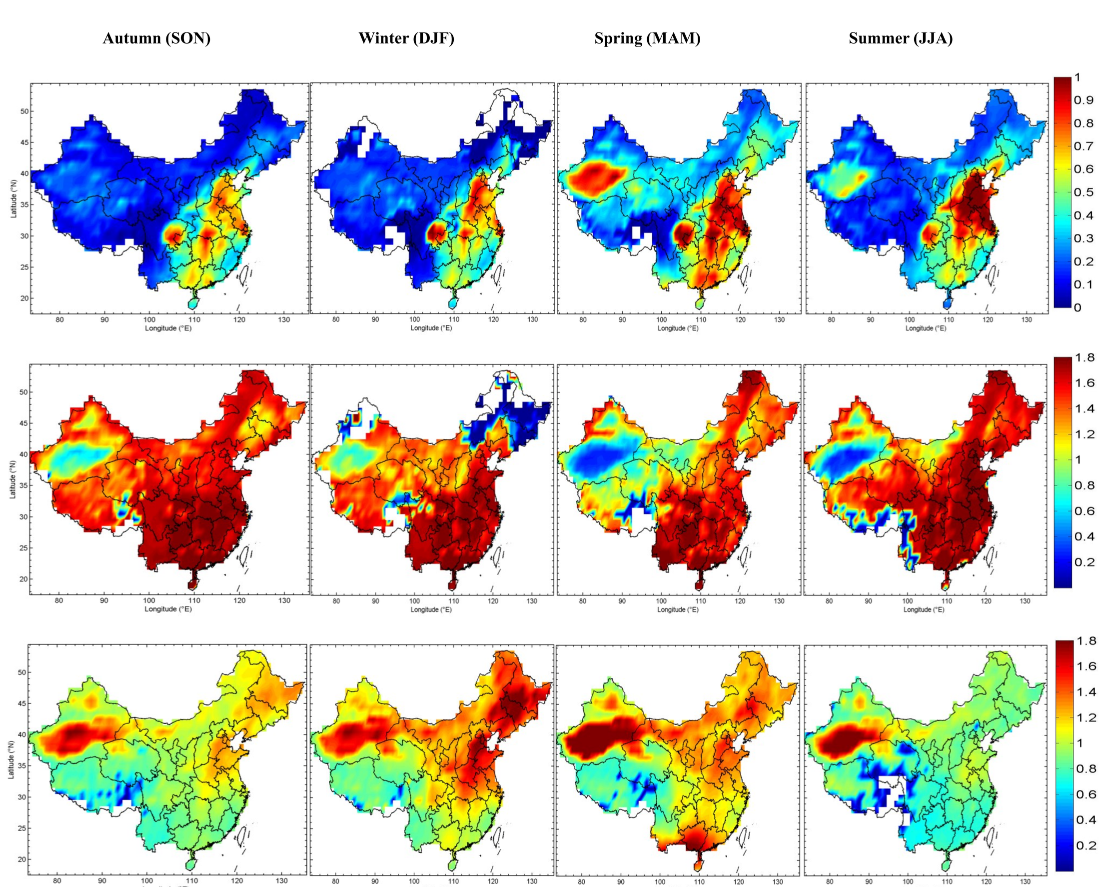
The solid red lines in all panels indicate significance of data evaluated at 95% confidence level. Across all the months, positive trends in AOD were generally found in arid areas of west and northwest of China ascribed to an increase in dust particles.

Seasonal mean spatial trends

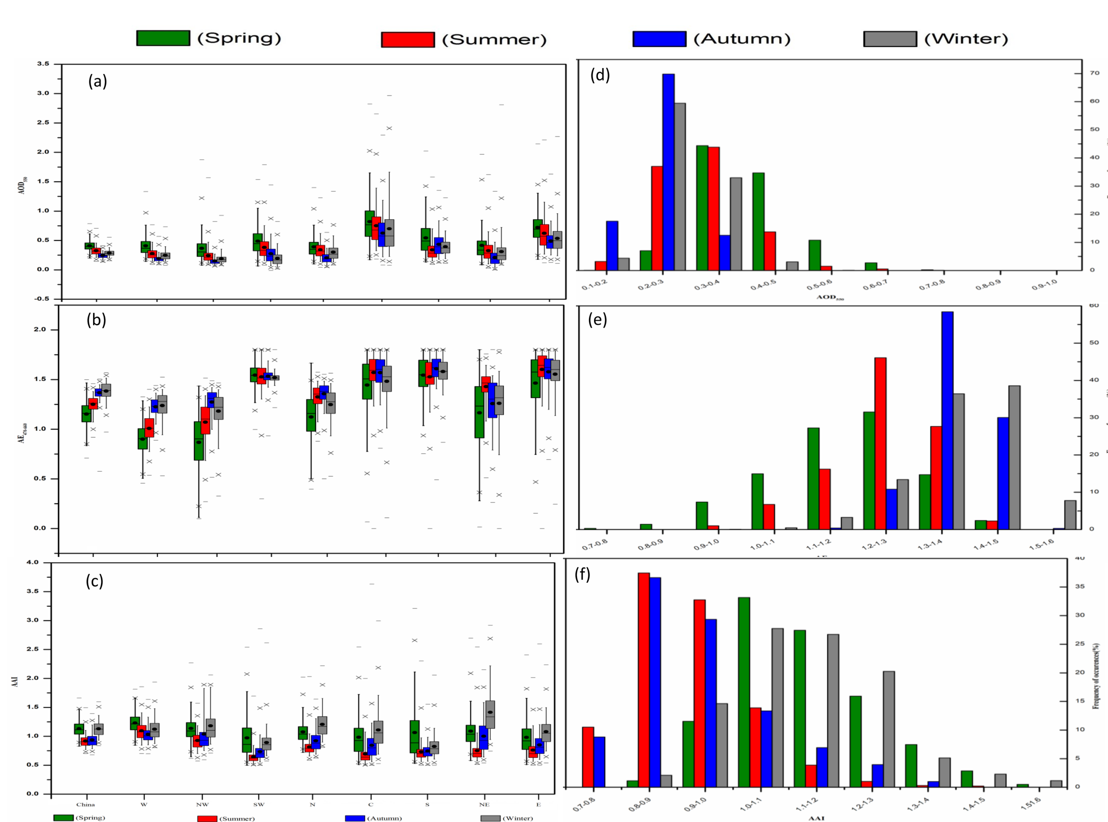


The solid red and white (bottom panels only) lines represent data significance evaluated at 95% confidence level.

Seasonal and Frequency distributions



The spatial mean distributions of different seasons. The first line for AOD; The second line for AE ; The third line for AAI.



a-c Seasonal mean variations and d-f frequency of occurrences of a, d AOD_{550}, b, e $AE_{470\text{-}660}$, and c, f AAI over mainland China and its provincial divisions. The labels of provincial divisions are abbreviated under "Results and discussion" section. The frequency distributions are presented only for the entire China.

Conclusions

- High concentrations of AOD550 were characterized by high values of AE470-660 and AAI noticed over eastern and southern China; while low AOD centers were observed over west, southwest, northeastern, and northern parts of China.
- Seasonally, high AOD values were sequenced from high to low as spring, summer, autumn, and winter seasons. The high AOD during spring has been attributed to dust and airborne sand particles and frequent dust storm events, while high values of AOD and AE during summer have been attributed to the increased anthropogenic activities from biomass burning, the hygroscopic growth of aerosols, and secondary aerosol formation through gasto-particle conversion processes resulting from high temperatures and relative humidity.
- The annual and seasonal spatial trend analysis revealed a decreasing trend in AOD in most regions of China, except southwest China where it showed a positive (increasing) trend.

References

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Email: 85482185@qq.com