Spatial and temporal variation of the Visible Infrared Imaging Radiometer Suite (VIIRS) derived aerosol optical thickness over East China

Fei Meng[a, b], Changyong Cao[c], Xi Shao[a]

[a]Department of Astronomy, University of Maryland, College Park, MD, USA

[b]Department of Civil Engineering, Shandong Jianzhu University, Jinan, PR China

[c]NOAA/ NESDIS/STAR, College Park, MD, USA

Abstract

The spatial and temporal variations in regional aerosol optical thickness (AOT) were investigated over Shandong province of China based upon one year's Visible Infrared Imaging Radiometer Suite (VIIRS) data. The regional forest background annual mean AOT was 0.467 with a standard deviation of 0.339, which was much higher than the background continental AOT level of 0.10. Higher AOT values for the study region were mainly found in the spring and summer, especially from May to August, while the lowest mean aerosol values were seen in November and December. Urban areas all have obviously higher mean AOT values than the rural areas resulting from intense anthropogenic sources. Given that the forest background AOT represents the natural background level, anthropogenic emissions and secondary aerosol generation contribute approximately 0.352 to the aerosol loading in this region. Additionally, strong regional imbalance of AOT was found to be distributed over the study area. The maximum annual average AOT values occurred in inland cities, while the coastal cities usually have lower AOT values.

Introduction

Aerosols are ubiquitous and comprise one important component of the Earth- atmosphere system, and influence air quality, visibility and climate system and human health. It is shown that there is a tendency of increase in the atmospheric aerosol load due to human activities, including the industrial production chains and the operation of various transport systems on the land surface. Because of the role of atmospheric aerosols in human heath and climate change, many studies have been carried out on the retrieval of aerosol particle optical properties, their relationship with the PM2.5 and PM10 concentrations, temporal and spatial variations, and their influence on the climate system and atmospheric radiation, with the development of new techniques and instruments. However, there are still uncertainties because of the lack of adequate knowledge on the spatial and temporal variability of aerosol properties across the globe. Long-term continuous aerosol observations in a large region are still of great importance for a range of assessments and applications, including satellite aerosol data validation, radiative forcing computations and public health and climate change.

The study area is situated on the eastern coast of China, with an area of 15.6×104 km^2, at latitude 34.26° N–38.42° N, longitude 114.93° –122.46° E. Fig.1 shows the 18 sites under study, including the regional forest background (FB), Jinan (JNA), Qingdao (QD), Yantai (YT), Weihai (WH), Weifang (WF), Zibo (ZB), Tai'an (TA), Linyi (LY), Jining (JN), Rizhao (RZ), Laiwu (LW), Dezhou (DZ), Liaocheng (LC), Heze (HZ), Zaozhuang (ZZ), Binzhou (BZ) and Dongying (DY)

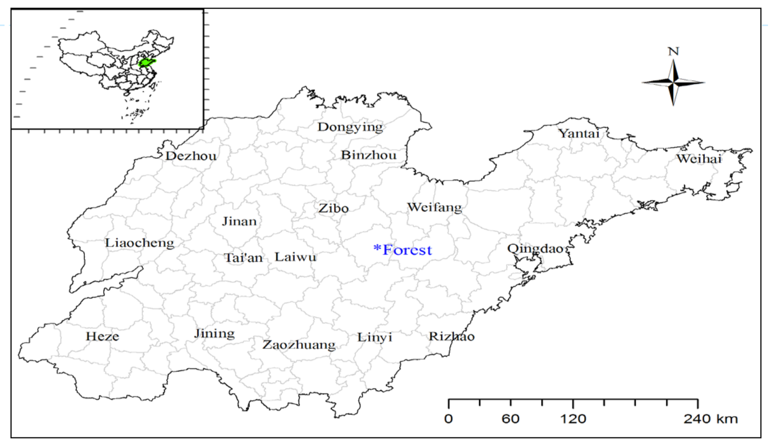


Fig. 1 Location of the study area. *Forest is the sampling location as forest background.

Methodology and Data

The VIIRS data

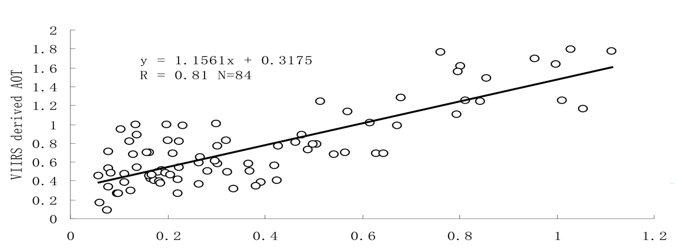
The VIIRS aerosol intermediate product (IP) data acquired in Shandong China from January 24 to December 31, 2013 (Fig. 1).

Spectral Range : 410-1250 nm, with 22 channels, of which 16 are M-bands (750 m resolution at nadir) and 5 are I-bands (375 m resolution at nadir)

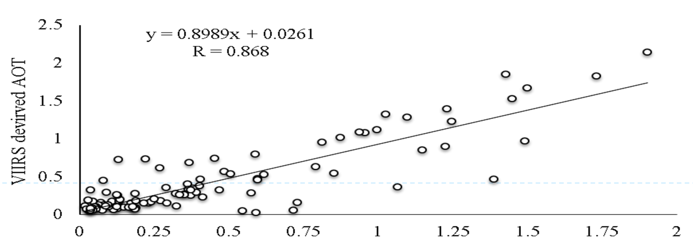
The combination of aerosol quality flags ≤ 1, cloud detection result quality flags = 0 and turbid/shallow water = 0 were used in AOT retrieval.

Validation

VIIRS derived AOT were compared with those from AERONET ground-based sun photometer data of Beijing and Xianghe sites. The correlation were shown in Fig. 2.



(a) Beijing



(b)Xianghe

Fig. 2 Comparison of VIIRS AOT with AERONET sun photometer-derived AOT

Results

Annual and seasonal AOT variations for different cities

Averaged over the measurements in 2013, the minimum (Min.), maximum (Max.), mean, standard deviation (Std.) and variance of AOT in 17 cities (Fig.1) are presented in Table 1.

In order to better understand the AOT values in different cities, percent days with AOT≤0.5, 1.0≥AOT > 0.5 and AOT > 1.0 respectively in each cities were calculated (Fig.2).

Table 1 Statistical annual AOT data in cities of Shandong province

City	N	Min.	Max.	Mean	Std.	Variance
weihai	201	0.023	1.902	0.540	0.409	0.167
yantai	188	0.071	1.791	0.596	0.409	0.167
qingdao	201	0.050	1.352	0.626	0.322	0.104
Rizhao	189	0.038	1.844	0.713	0.437	0.191
Weifang	193	0.093	1.901	0.747	0.428	0.184
Laiwu	163	0.045	1.731	0.747	0.410	0.168
Binzhou	146	0.048	1.871	0.767	0.500	0.250
Zibo	185	0.074	1.884	0.805	0.454	0.206
Zaozhuang	142	0.084	1.859	0.806	0.435	0.190
Dongying	158	0.086	1.900	0.808	0.504	0.254
Taian	176	0.072	1.964	0.816	0.442	0.195
Jining	165	0.118	1.952	0.823	0.433	0.188
Heze	156	0.168	1.941	0.826	0.441	0.195
Jinan	160	0.113	1.794	0.839	0.448	0.200
Liaocheng	171	0.137	1.894	0.846	0.452	0.204
Dezhou	185	0.096	1.895	0.853	0.478	0.229
Linyi	200	0.126	1.872	0.905	0.418	0.175
Forest	183	0.01	1.583	0.467	0.339	0.115

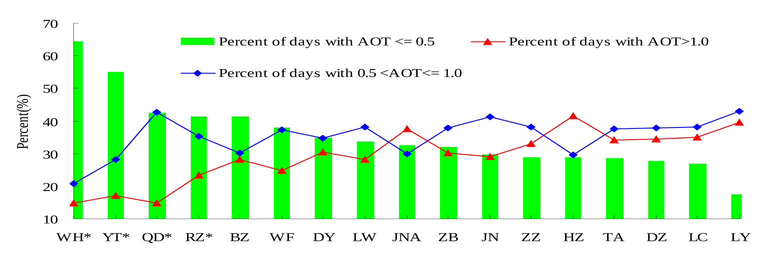


Fig.2 Percent of days with different AOT thresholds. "*" mean costal city.

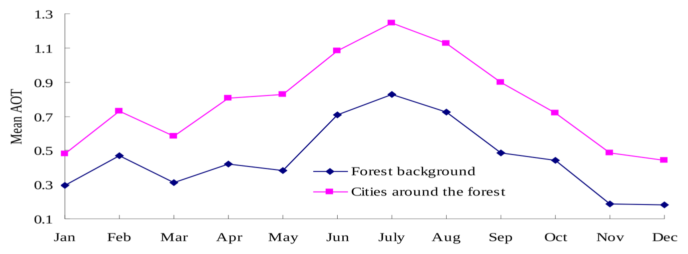


Fig. 3 Monthly mean AOT in the regional forest background and nearby cities in

(e)

Spatiotemporal pattern of AOT

To investigate the spatial and temporal variation of regional AOT, statistical analysis was performed. 17 main cities plus the forest background were studied. Fig.3 shows variations of monthly mean values of retrieved AOT over the forest background site (FB) and cities around it. Fig.4 also shows a large seasonal variation that AOT varied from 0.260±0.240 (Winter) to 1.226±0.401 (Summer). Urban seasonally averaged in summer was always higher than values in other seasons, varied from 0.754±0.449 (WH) to 1.226±0.356 (JNA). The results in Fig.5 show a seasonal cycle of AOT with the lowest values recorded in winter and autumn and maximum values obtained in summer and spring. The time series of daily AOT and 7-day moving average line from January to December 2013 are illustrated in Fig.6 with a strong seasonal variation in 4 typical cities: Jinan, Linyi, Jining and Weihai. Fig.7 shows the AOT movement between August 17 and 18.

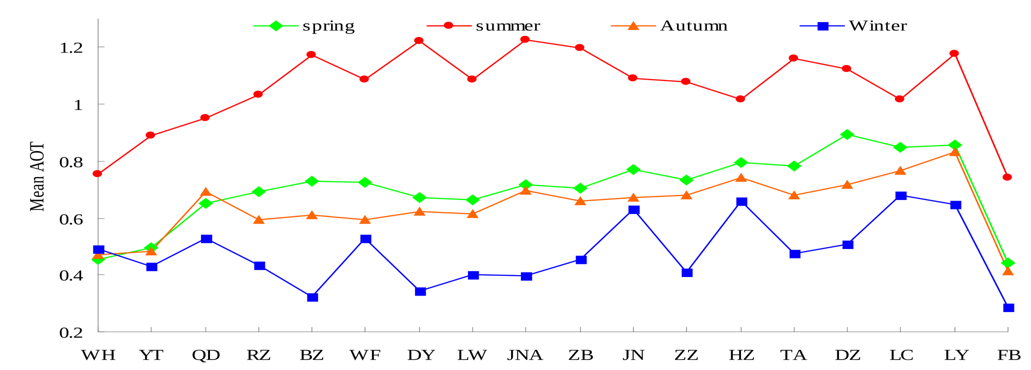


Fig. 4 Statistical seasonal overview of mean AOT in different cities of Shandong

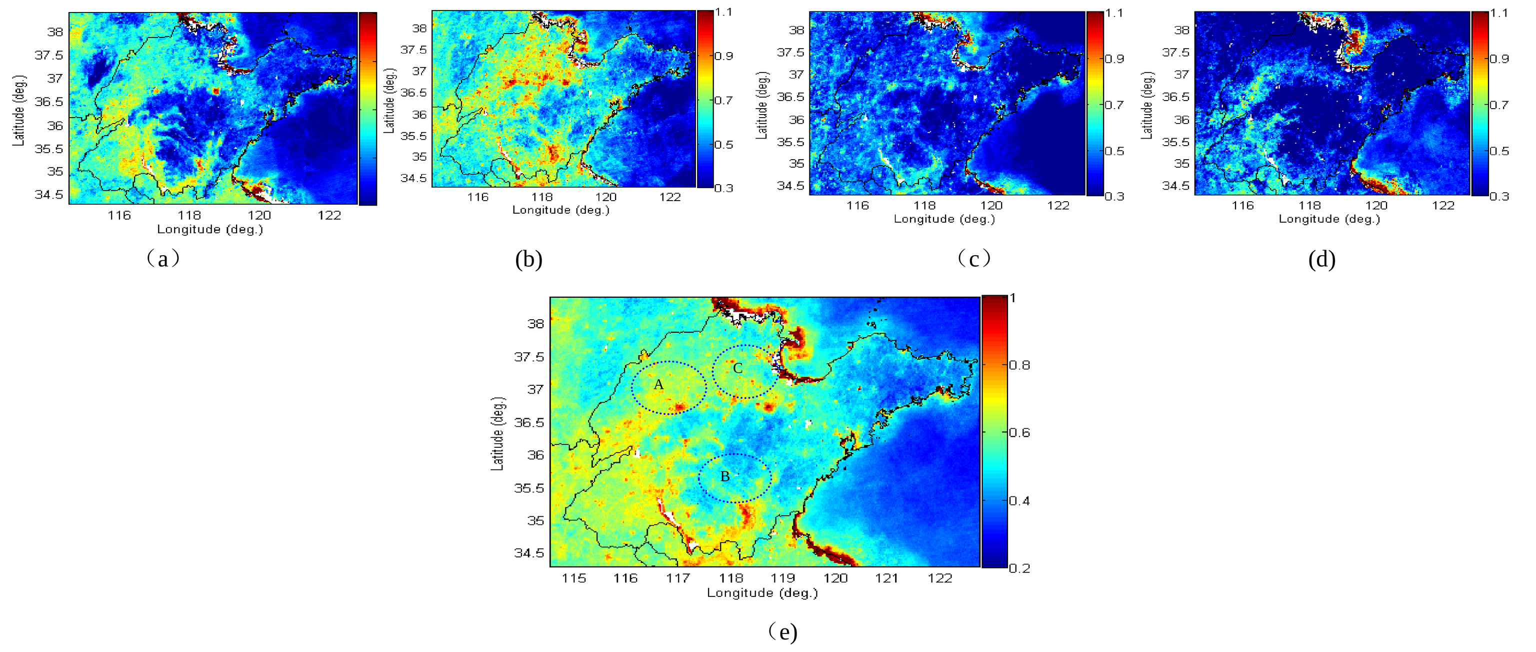


Fig.5 Seasonal mean VIIRS AOT observed in (a) spring (March to May 2013), (b) summer (June to August 2013), (c) Autumn (September to November 2013), (d) winter (December to February, 2013) and (e) annual in 2013. A is Jinan Jinan metropolitan, B is Linyi urban belt and C is Zibo urban belt.

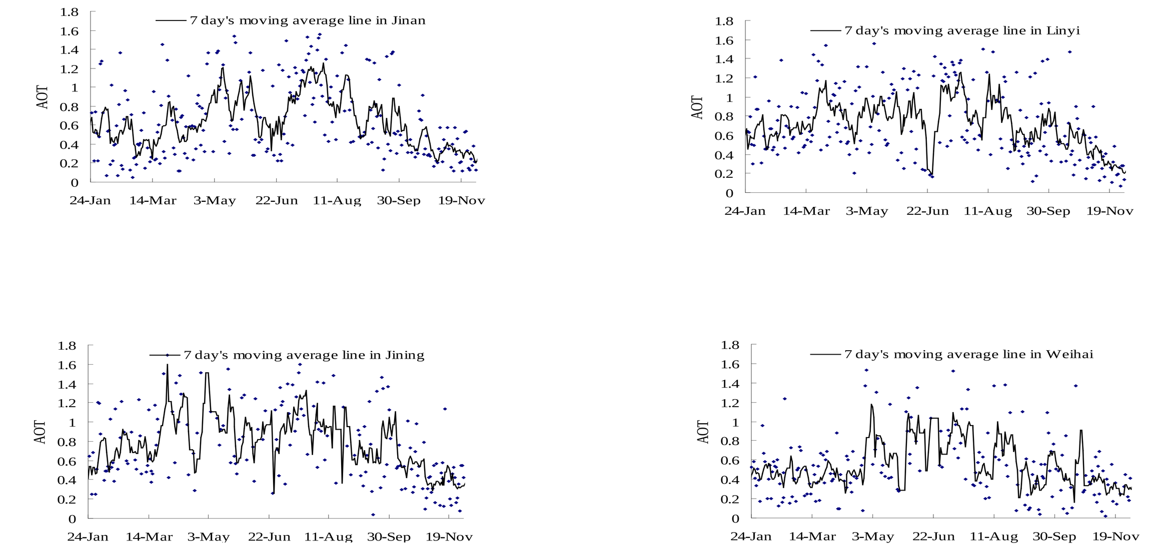
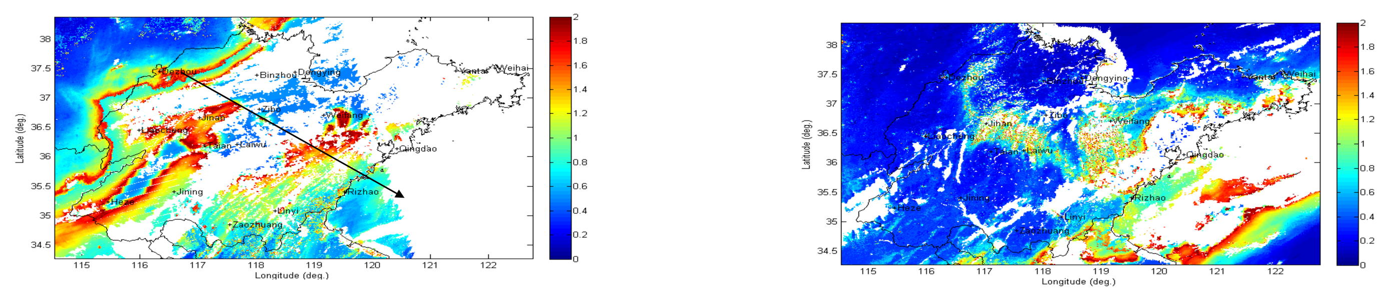


Fig. 6. Scatter plots of daily AOT and 7 day's moving average line of Jinan, Linyi, Jining and Weihai in 2013.



(A) August 17, 2013

(B) August 18, 2013

Fig. 7. Distribution of AOT retrieved with VIIRS during a heavy polluted event from August 17 to 18, 2013. The black arrow is the AOT moving direction.

Summary

The forest background annual averaged AOT was 0.467 with a standard deviation of 0.339, which was much higher than the background continental AOT level of 0.10.

Higher AOT values for the study region were mainly found in the spring and summer, especially from May to August, while the lowest mean aerosol values were seen in November and December. The sequence of seasonally mean AOT values was summer > spring > autumn > winter.

Urban areas all have obviously higher mean AOT values than the rural areas resulting from intense anthropogenic sources. Given that the forest background AOT (annual mean 0.467) represents the natural background level, anthropogenic emissions and secondary aerosol generation contribute approximately 0.352 to the aerosol loading in this region.

Strong regional imbalance of AOT was found to be distributed over the study area. The maximum annual average AOT values occurred in inland cities, while the coastal cities usually have low AOT values.