Reviewer 2

General comments

This paper characterizes the climatology of aerosol microphysical and optical properties in China using ground-based remote sensing from the CARSNET network. This is one of the most systematic dataset of aerosol optical properties reported in the literature, and is valuable for improving the estimate of aerosol radiative effects and for evaluation of satellite data and climate models. The paper is generally well written. I think it can be considered for publication after the author addresses the following minor comments and suggestions. Besides the following comments, however, there are many outstanding grammar errors in the paper. I strongly suggest that the author ask a native speaker to carefully edit and improve the language.

Response: Thanks for the reviewer's important and constructive comments and suggestions. Some minor comments and suggestions have been revised carefully in the manuscript. Moreover, the grammar has been carefully checked in the paper and the language of this manuscript has been improved by a native speaker.

Special comments:

(1) Line 72-77: The descriptions of the roles of AOD, absorptivity, and SSA are very similar. Please revise a bit to reflect their respective roles.

Response: According the reviewer's suggestions, the descriptions of the roles of AOD, absorptivity, and SSA has been modified to reflect their roles, respectively. The text is as follows:

"Aerosol optical depth (AOD) is one of the key measures of the total aerosol extinction effects on climate (Breon et al., 2002), and the extinction Ångström exponent (EAE) with spectral dependence can be used to obtain the information about aerosol size distributions (Gobbi et al., 2007; Eck et al., 1999). The aerosols' absorptivity is a key determinant of absorption on composition and to calculate the direct aerosol radiative effect (Haywood and Shine, 1995), and the single scattering albedo (SSA) is the parameter has spectral dependence to distinguish major aerosol particle types (Jacobson et al., 2000; Dubovik et al., 2002; Gelencser et al., 2004; Russell et al., 2010; Giles et al., 2012)".

(2) Line 241-243: Which radiative transfer model is used to calculate the direct aerosol radiative effect?

Response: Following the reviewer's suggestions, the radiative transfer model of Discrete Ordinates (DISORT) approach was used to calculate the direct aerosol radiative effect which has been descript in the manuscript line 261-264.

(3) Line 258-259: The assumption of single fixed aerosol vertical distribution (exponential to 1 km) may deviate from the real-world situation significantly. What's the potential impact on calculated aerosol radiative effect?

Response: Thank for the reviewer's comments. Firstly, according to the Zhao et al. (2019, AE) pointed out that the distribution of annual MLH in the most land regions of China were less than 1km. Aerosols are mainly distributed within the mixing layer in the atmosphere and usually decrease with the increase of mixing layer height. Therefore, this paper assumes 1 km to calculate the radiation flux is reliable and reasonable. In addition, the single fixed aerosol vertical distribution (exponential to 1 km) assumed in this study were to be consistent with other previous researches in the world, which also adopted this standard.

(4) Line 260-262: What does this error refer to and how is it quantified?

Response: Thank for the suggestions of reviewer. "The error for the observed solar radiation at the surface in global was +2.1 ± 3.0% for an overestimation of about +9 ± 12 Wm^{-2}." was refer to García et al. (2008). The text has been modified as "García et al. (2008) pointed out that the error for the observed solar radiation at the surface in global was +2.1 ± 3.0% for an overestimation of about +9 ± 12 Wm^{-2}.".

Moreover, García et al. (2008) found that a small overestimation of 9 ± 12 Wm^{-2} for measured radiation in global terms within the uncertainty of solar measurements by BSRN (Baseline Surface Radiation) and SolRad-Net (Solar Radiation Networks) observed data.

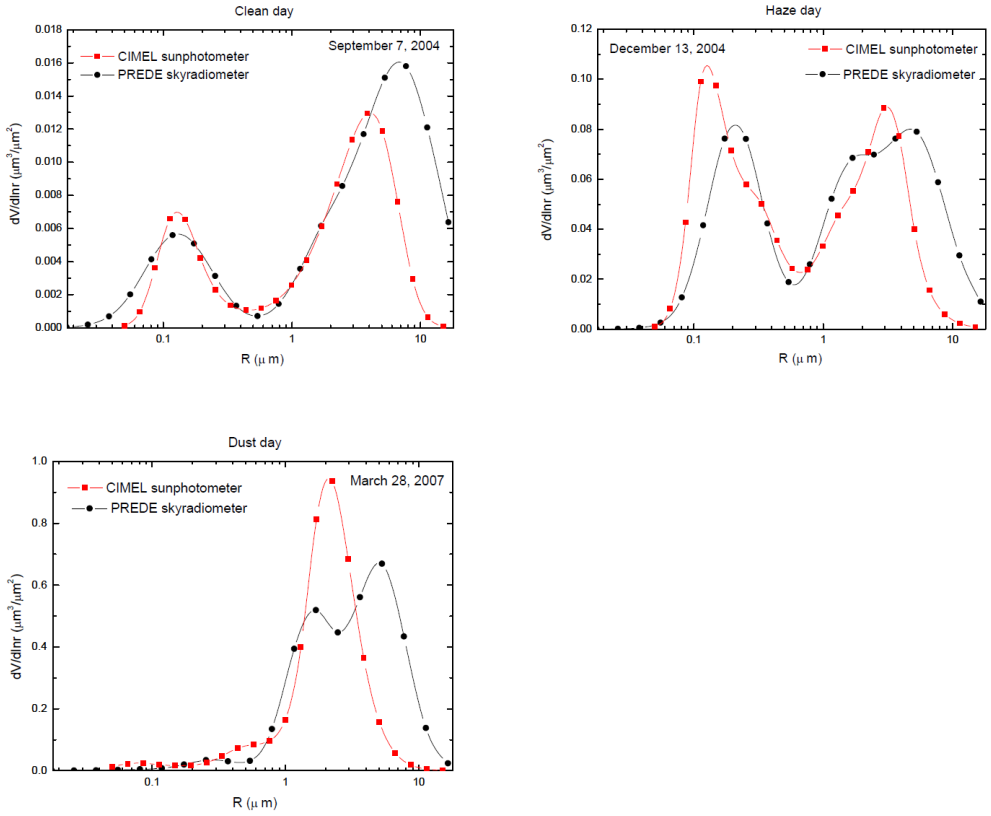
(5) Line 285-287: PVF and PVC have been defined before (Line 216) and the full names used in these two places are different. Please define only once and use consistent terms.

Response: Thanks for the suggestions. The "PVF" and "PVC" have been defined as "PV_F" and

"PV_C" to make consistent throughout the text in the revised paper.

(6) Line 314-316: In urban sites, the volume concentration of coarse particles is higher than fine particles, which sounds counterintuitive. Does this agree with previous studies?

Response: The authors agree with the reviewer's opinion. Firstly, the volume concentration of fine particles is higher than that of the coarse particles at most of the pollution period; but during the non-pollution period, the volume concentration of coarse particles is higher than fine particles. Che et al. (2008, ACP) has investigated that the volume concentration of coarse particles is higher than fine particles in the clean day as can be seen in the figure below. The results of this manuscript are a multi-year average and agree with previous studies. Moreover, Zhao et al. (2018, JGR) has also found the larger volume concentration of coarse mode particles than fine mode particles in the industrial-urban site of Fushun in Northeastern China. Finally, in these 23 urban sites of this study, there are almost 15 cities in Northern China, where have less precipitation and higher fugitive dust contribution level. These climatic conditions could lead to the higher volume concentration of coarse particles in such urban sites.



(7) Line 334-335: The several studies listed here did not support the hygroscopic growth of fine-mode particles.

Response: Thanks for the reviewer's comments. More references have been added to supplement the hygroscopic growth of fine-mode particles in the revised version. The text is as follows:

"Cheng et al. (2015) found different aerosol volume size distributions for dust and sea salt at Shanghai in the eastern China, and they showed that their relative abundances varied with season and in response to local or long-range transport. Zhao et al. (2018) also reported the effect of sea salt aerosol on the aerosol absorption and radiative effects in the coastal region over northeastern China. Especially the particles hygroscopic growth with different composition observed in special climatic conditions could affect aerosol microphysical properties by geographically variable effects (Zhang et al., 2015; Sun et al., 2010). Like in the YRD region, hygroscopic growth of fine-mode particles could lead to larger AOD and scattering enhancing reported by Sun et al. (2018) and Che et al. (2018). Xia et al. (2019) observed the aerosol hygroscopic growth on fine particle scattering coefficient in Beijing.".

Moreover, some references has been added as following:

Sun, J. Y., Zhang, Q., Canagaratna, M. R., Zhang, Y. M., Ng, N. L., Sun, Y. L., Jayne, J. T., Zhang, X. C., Zhang, X. Y., and Worsnop, D. R.: Highly time- and size-resolved characterization of submicron aerosol particles in Beijing using an Aerodyne Aerosol Mass Spectrometer, Atmos. Environ., 44, 131-140, 2010.

Sun, T., Che, H., Qi, B., Wang, Y., Dong, Y., Xia, X., Wang, H., Gui, K., Zheng, Y., Zhao, H., Ma, Q., Du, R., and Zhang, X.: Aerosol optical characteristics and their vertical distributions under enhanced haze pollution events: effect of the regional transport of different aerosol types over eastern China, Atmos. Chem. Phys., 18, 2949–2971, https://doi.org/10.5194/acp-18-2949-2018, 2018.

Xia, C., Sun, J. Y., Qi, X. F., Shen, X. J., Zhong, J. T., Zhang, X. Y., Wang, Y. Q., Zhang, Y. M., and Hu, X. Y.: Observational study of aerosol hygroscopic growth on scattering coefficient in Beijing: A case study in March of 2018, Sci. Total Environ., 685, 239-247, 2019.

Zhang, L., Sun, J. Y., Shen, X. J., Zhang, Y. M., Che, H., Ma, Q. L., Zhang, Y. W., Zhang, X. Y., and Ogren, J. A.: Observations of relative humidity effects on aerosol light scattering in the Yangtze River Delta of China, Atmos. Chem. Phys., 15, 8439-8454, https://doi.org/10.5194/acp-15-8439-2015, 2015.

(8) Line 369, Line 577: Wuhan is not located in the YRD region.

Response: According to the reviewer's suggestion, the location of Wuhan has been checked and modified to central China all through the text.

(9) Line 583-585: Why is the DARE-TOA positive in Akedala? Due to a strong absorption?

Response: Thanks for the important suggestions. We checked the value of DARE-TOA in Akedala, it should be corrected as -0.42 W/m2 in the text by a typing mistake. Moreover, the value was correct in the relevant descriptive sentences, Table and charts through the text.

(10) Line 610-612: I think the strong cooling is not due to strong absorption.

Response: According to the reviewer's helpful suggestion, the sentences "The high DARE-TOA values at these urban sites imply relatively strong cooling effects due to moderate to strong light absorption by the particles." has been revised as "The high DARE-TOA values at these urban sites imply relatively strong cooling effects due to higher aerosol loadings in the atmosphere.

(11) Fig. 2, 3, 8: The scales of the legend should be modified to differentiate large and small values more clearly. For example, in Fig. 8, most values fall between -40 and 0 and hence show the same color.

Response: Thanks for the suggestions. The legend scales of Figure 2 - 8 have been changed in the revised manuscript to differentiate large and small values more clearly as follows:

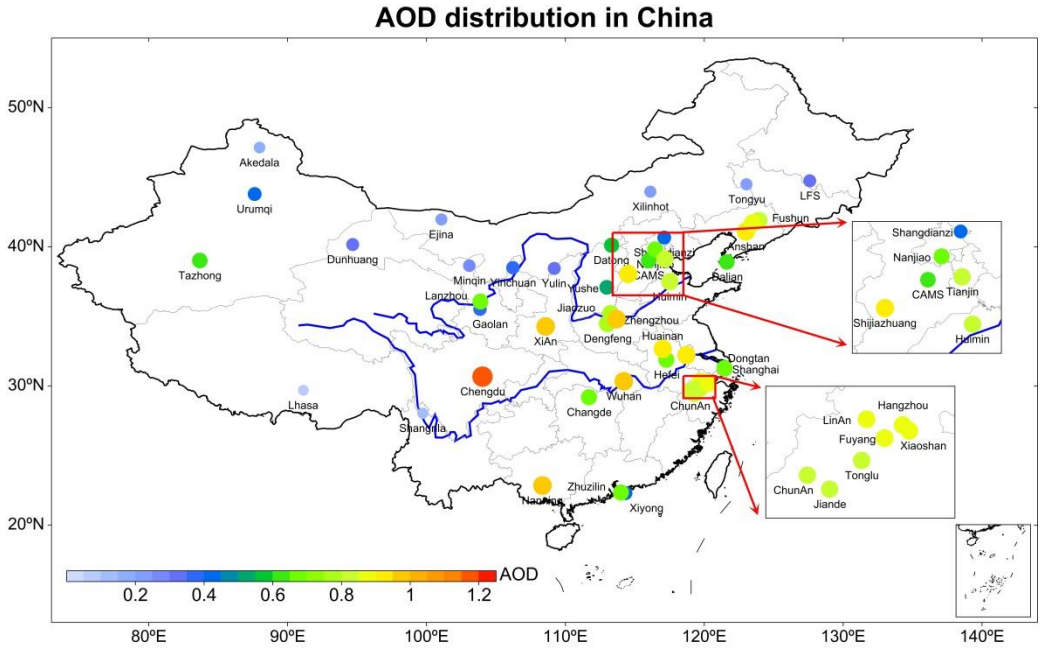


Figure 2. Annual spatial distribution of aerosol optical depth (AOD) at 440 nm at the CARSNET sites

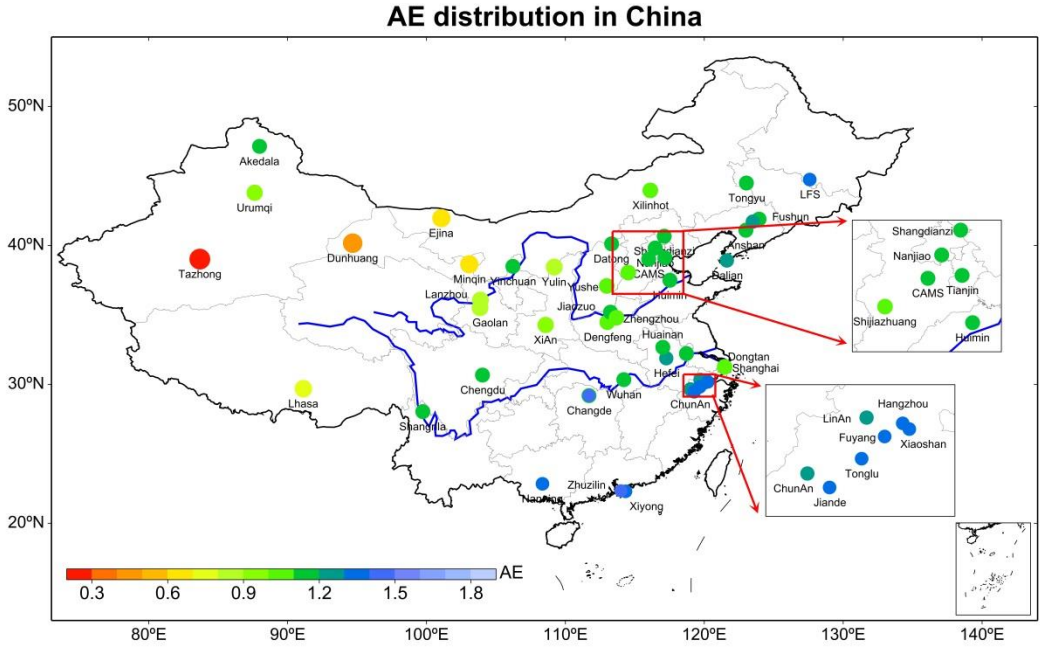


Figure 3. Annual spatial distribution of extinction Ångström exponent (AE) 440-870 nm at the CARSNET sites

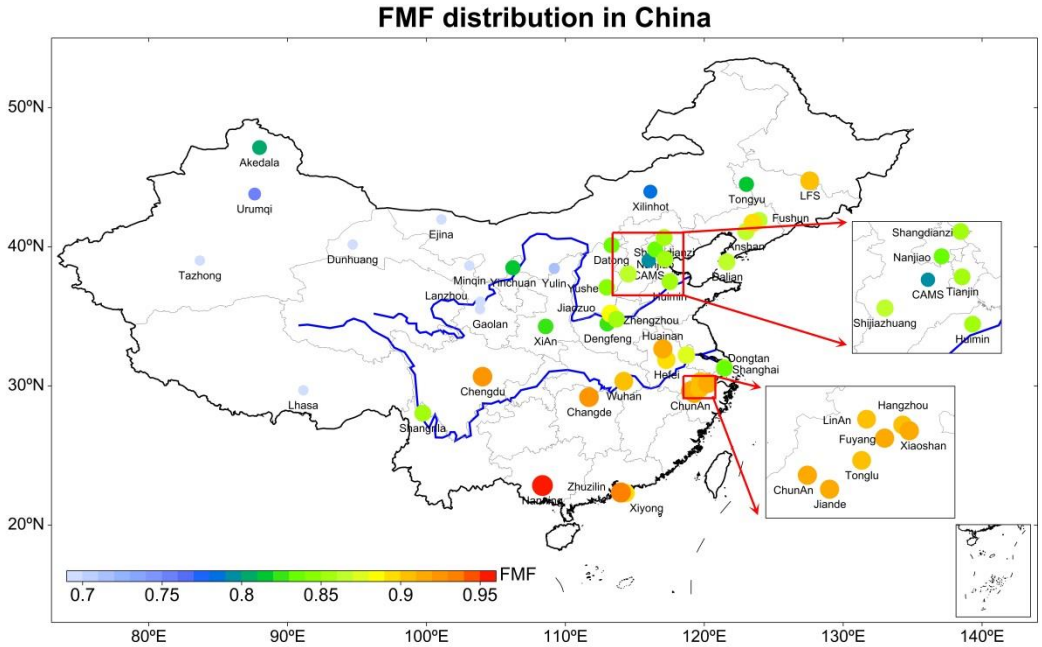


Figure 4. Annual spatial distribution of fine mode fraction at the CARSNET sites

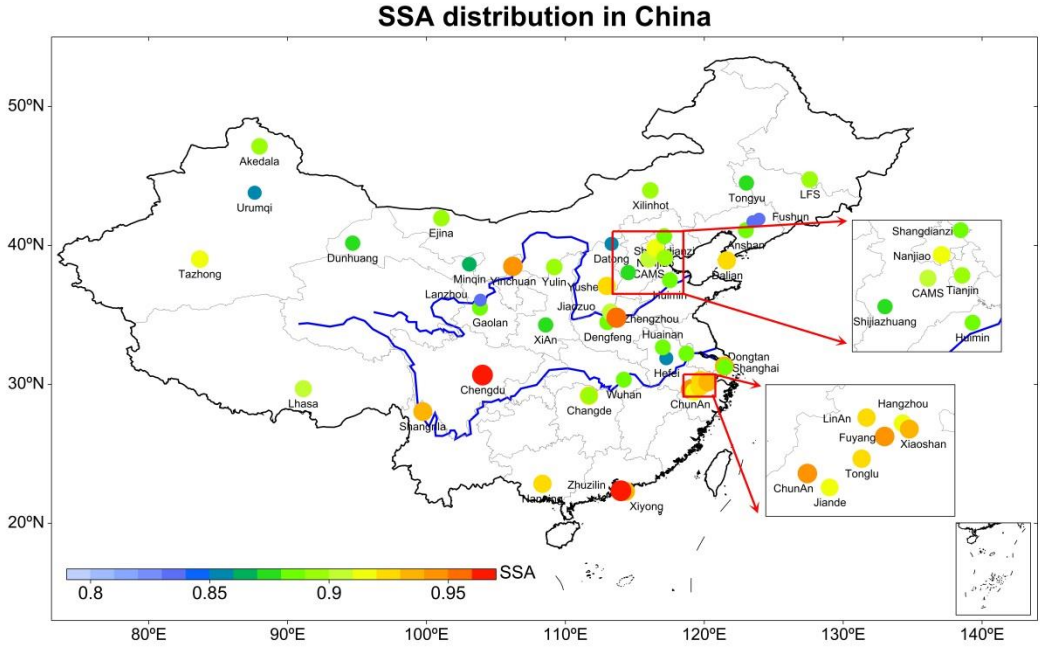


Figure 5. Annual spatial distribution of the single scattering albedo (SSA) at 440 nm at the CARSNET sites

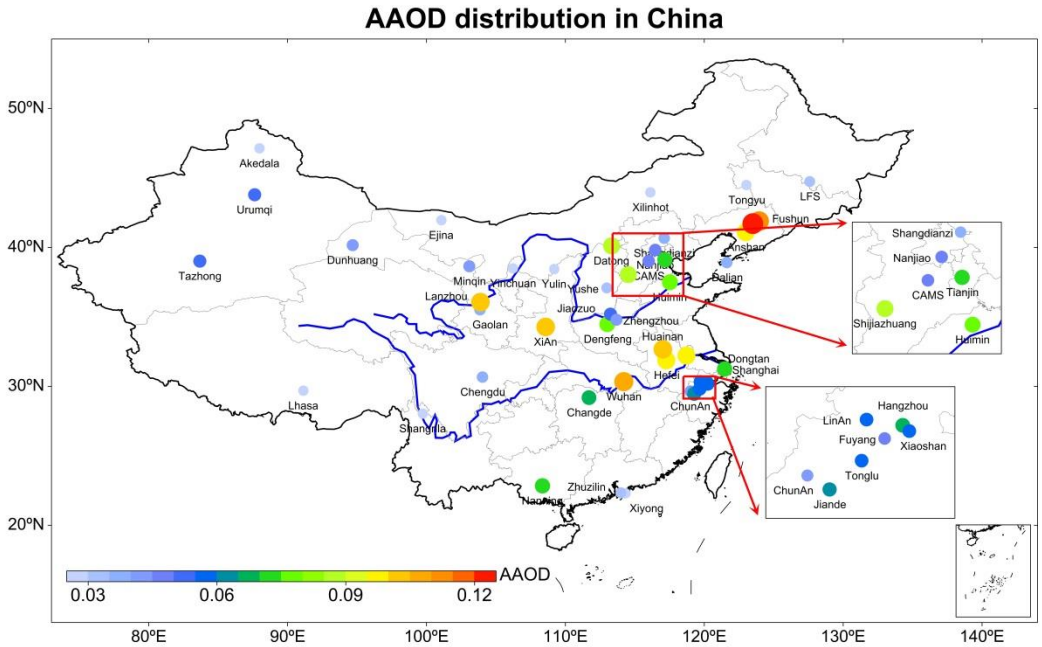


Figure 6. Annual spatial distribution of absorption aerosol optical depth (AAOD) at 440 nm at the CARSNET sites

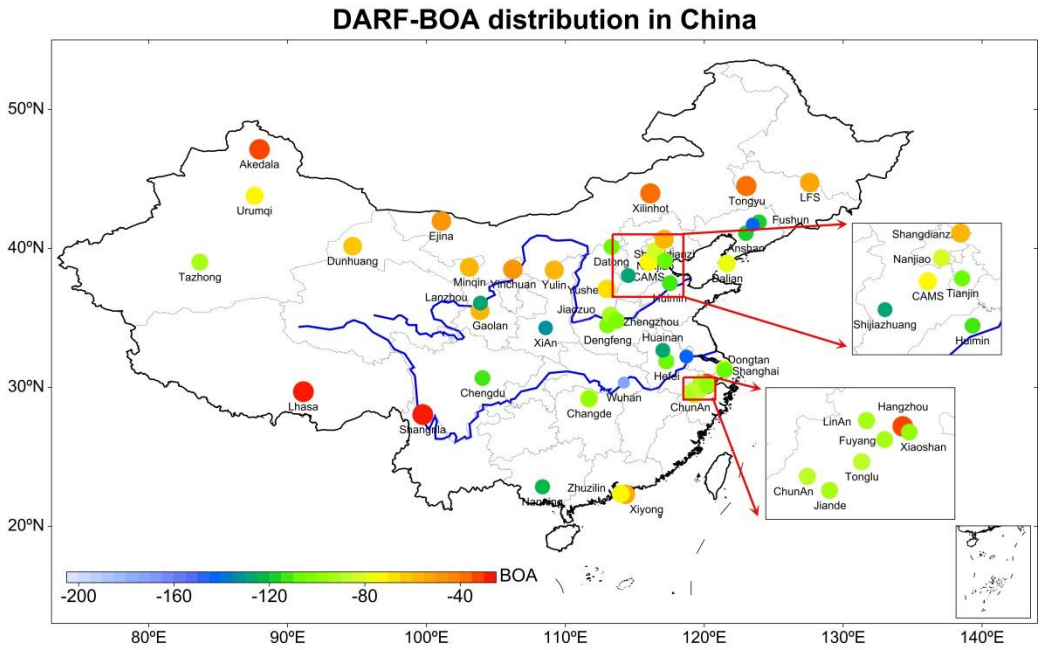


Figure 7. Annual spatial distribution of direct aerosol radiative effect at the bottom of the atmosphere at the CARSNET sites

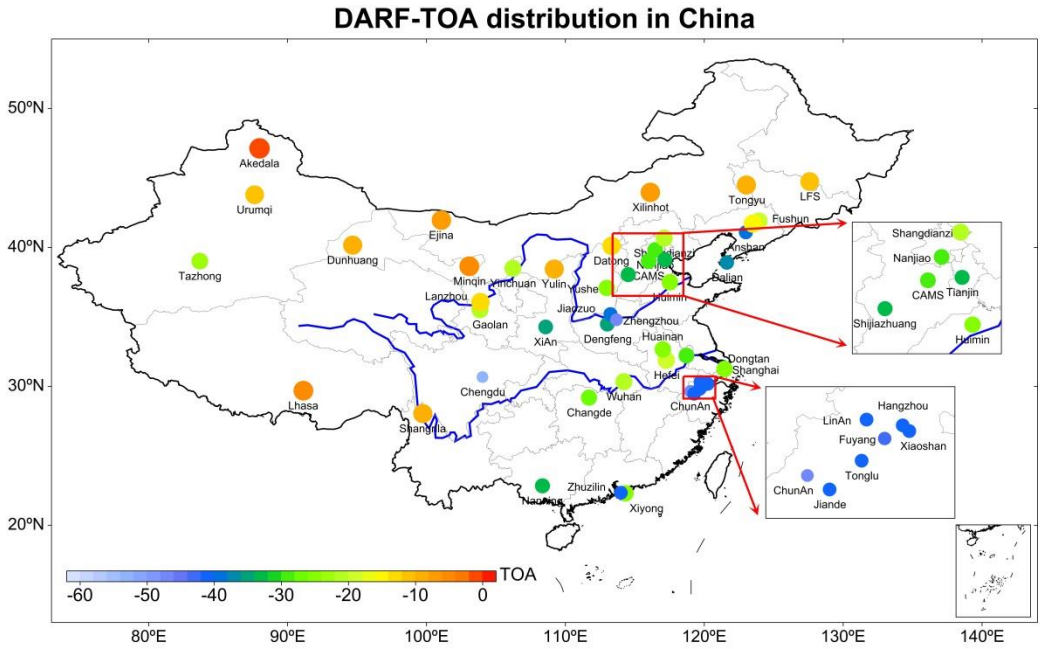


Figure 8. Annual spatial distribution of direct aerosol radiative effect at the top of the atmosphere at the CARSNET sites