We appreciate the reviewer' valuable comments and constructive suggestions, which help improve the quality of the manuscript. We have carefully revised the manuscript according to these comments. The reviewer`s comments are in black, our responses are in blue and the corresponding changes in manuscript are in red.

Anonymous Referee #1

General Comments: This paper overall contains some useful information on the SKYNET measurements and retrievals. However, I feel the material does not meet the standards of an AMT publication since these is relatively little new information that is not already in the scientific literature and therefore does not present significant or substantial scientific progress in remote sensing of aerosols. I urge the authors to submit this paper to a different journal since there are some analyses that may provide some insight into aerosol properties in Beijing. Additionally, the paper is poorly written with numerous issues such as lack of clarity on dates utilized for analysis, poor statistical representativeness (only one pollution event and one dust event), incomplete or even erroneous descriptions of AERONET measurements and/or algorithms, and in some cases poor choices of comparison metrics. I provide numerous examples of these issues and other issues below in Specific Comments so that these may be improved in a revised submission.

Response: Thank you for your valuable comments and constructive suggestions. We have modified the expressions in a proper way. The comparison metrics include RMSE, MBD and correlation coefficient in the revised manuscript. The frequency distribution of AERONET-retrieved AOPs has given in the revised manuscript comparing with SKYNET-retrieved AOPs for the four seasons. We have added the AERONET data in the pollution event analysis to compare with SKYNET data, and the poor statistical results (only one pollution event and one dust event) has removed. The comparison of AERONET and SKYNET data on the three days are shown instead. Some detail responses are in the following:

Specific Comments:

Line 14, Abstract: Correlation coefficient is not the best way to compare AOD from these two networks. Better comparison metrics for AOD would be RMS differences and bias.

Response: Following the reviewer's comment, the RMSE and MBD have added in the revised manuscript. (Line 14-18)

'The results obtained from simultaneous measurements compare well (RMSE of 0.010-0.020) and show high correlation coefficients (> 0.996) for aerosol optical depth (AOD) at each wavelength. The highest correlation coefficient for Ångström exponent (when AOD_{440nm}>0.4) is 0.992, at 440–870 nm, with the smallest RMSE of 0.042. The RMSE of single scattering albedo (SSA) between SKYNET and AERONET is as low as 0.018 at 440 nm, with high correlation coefficient (0.851), and adjusting the sky-radiance calibration constant and surface albedo input values can easily affect the value of SKYNET SSA. The real and imaginary parts of the refractive index show deviations of 0.031-0.055 and 0.003-0.005 respectively for all the wavelengths.'

Line 16, Abstract: The SVA cannot be changed as it is a characteristic of the hardware of the instrument. I assume you might mean calibration adjustment therefore this should be reworded.

Response: We have replaced 'SVA' with 'sky-radiance calibration constant'. (Line 17)

'while the sky-radiance calibration constant and surface albedo input values can affect the value of SKYNET SSA.'

Line 17-19, Abstract: For size distributions it is more important to compare the modal or peak sizes of both the fine and coarse modes for the 2 retrievals rather than comparing the volume.

Response: The comparison of the fine and coarse modes has added, and the appropriate description about the comparison results has shown in the revised manuscript. (Line 19-22)

'The fine mode and coarse mode dominated volume size distribution patterns derived from the two networks' instruments are both bimodal but the coarse-mode volume concentration in coarse mode dominated condition is much larger that in fine mode dominated, meanwhile the coarse-mode volume of SKYNET is larger than that of AERONET on average.'

Line 17-19, Abstract: Be clear here on how many cases were utilized to compute these comparisons. It seems to me that the sample size of one pollution event and one dust event compared to one clear event is not nearly large enough to be statistically robust.

Response: Following the reviewer's comment, the revised manuscript now has modified the sentences. We have shown a clear date in the description of the statistics. (Line 31-34)

'The AOD shows high consistency for the SKYNET skyradiometer and AERONET sunphotometer on the clean day (27 December 2016), light-pollution condition (2 January 2017) and heavy-pollution condition (4 January 2017), and the RMSE are about 0.005, 0.006 and 0.018 respectively. The RMSE of SSA are 0.022, 0.046, 0.020 and for Ångström exponent are 0.229, 0.289, 0.060, respectively, the large biases of Ångström exponent are due to the low AOD values.'

Line 45, Introduction: Please mention here that AERONET is global, as compared to the regional SKYNET.

Response: It has mentioned in the sentence in the revised manuscript. (Line 47-49)

'Ground-based measurement networks are a very useful and accurate way to monitor the spatiotemporal distribution of aerosols (Holben et al., 2001) by using the sun-sky radiometric technique (Holben et al., 1998). SKYNET (Nakajima et al., 2007; Takamura and Nakajima, 2004), located mostly in Asia and Europe, is a regional observation network dedicated to aerosol–cloud–radiation interaction research (Nakajima et al., 1996; Nakajima et al., 2007; Che et al., 2014). AERONET (Aerosol Robotic Network; Holben et al., 2001) is a global well-known ground-based remote-sensing aerosol network, established by NASA (National Aeronautics and Space Administration) and PHOTONS (Photométrie pour le Traitement Opérationnel de Normalisation Satellitaire).'

Line 60, Introduction: This line about the Pandithurai et al. (2009) reference should be removed, it does not fit or make sense here.

Response: This line about the Pandithurai et al. (2009) reference has removed in the revised manuscript. (Line 63)

Line 66-67, Introduction: Very poorly written, were all AOPs in the best agreement at 675 nm, including the AOD?

Response: Sorry, it should be AODs. The sentence has modified in the revised manuscript. (Line 69)

'Evgenieva et al. (2008) compared the AODs between AERONET and SKYNET using two days of measurements and found the lowest deviation to be at 675 nm.'

Line 68-69, Introduction: Why do you not provide a summary of the Estelles et al. (2012) results when you did for the other comparison papers that you referenced?

Response: The more detail description has added in the sentence in the revised manuscript. (Line 73-74)

'Estellés et al. (2012) then compared the differences between AERONET and SKYRAD4.2 inversion products retrieved from one month of Cimel data showing RMS differences of 0.025-0.049 for SSA, 0.005-0.034 and 0.004-0.007 for the real and imaginary parts of the refractive index, respectively.'

Line 78-79, Introduction: This is the wrong reference (Mok et al., 2016) for this analysis package. Note that in the first sentence of section 2.2 you give a web address for this package. This is an example of errors and lack of attention to detail in this manuscript.

Response: The wrong reference has removed in the revised manuscript. (Line 84)

Line 84, Section 2.1: Please be specific on the AERONET data used, did you analyze the Beijing-CAMS site data in Sep 2016 and the Beijing site data in March 2007? Also be clear here: are there only 2 months of data used in the comparisons between SKYNET and AERONET retrievals?

Response: Sorry for misunderstanding of previous statements, it has modified in the revised manuscript. The AERONET and SKYNET data sets from September 2016 to April 2018 are used for Section 3.1; while two networks` data sets from September 2016 to January 2019 are used for Section 3.2. (Line 90-91)

'The two instruments` measurements from September 2016 to April 2018 are used to analyze the differences between SKYNET and AERONET.'

Lines 89-90, Section 2.1: This is a very poor description of the Cimel spectral measurements of most of the AERONET network. The AOD measurements at most sites also include 340, 380, 500 and 1640 nm. Also, the three channel 870 nm-channel polarization measurements were made at only a few sites in AERONET and retrievals did not use these channels. Additionally, you need to include uncertainty values of the AERONET data, such at the 0.01-0.02 for AOD (Eck et al. 1999) and the 0.03 for 440 nm SSA when AOD>0.5 (Dubovik et al., 2001).

Response: According to the advice, the description of Cimel sunphotometer has modified, the uncertainty values of AOD and SSA have added in the revised manuscript. (Line 95-99)

'The sunphotometer is another automatic instrument for tracking the sun and scanning the sky, but with a 1.2° full field-of-view at the following channels: 340, 380, 440, 500, 675, 870, 940, 1020, and 1640 nm (Holben et al., 1998). Accuracy on AERONET AOD is 0.01-0.02 (Eck et al. 1999) and the uncertainty values of 440 nm SSA when AOD > 0.5 is 0.03 (Dubovik et al., 2001). In this study, AERONET data from four channels (440, 675, 870, and 1020 nm) and SKYNET data from five channels (400, 500, 670, 870, and 1020 nm) are used to retrieve AOPs over Beijing.'

Lines 99-100, Section 2.2: Again, an incomplete description here. The AERONET algorithm uses a mixture of both spherical and spheroidal particles, with the percentage spherical determined by the best fit to the measured sky radiances.

Response: A complete description following the advice has given in the revised manuscript. (Line 106-107)

'The AERONET algorithm uses a mixture of both spherical and spheroidal particles, with the percentage spherical determined by the best fit to the measured sky radiance.'

Line 104, Section 2.2: You should note that this results in an uncertainty in AOD ranging from 0.01 to 0.025 for overhead sun (optical airmass=1).

Response: A more detail description in the sentence has given in the revised manuscript. (Line 112)

'Campanelli et al. (2004) presented a new procedure for the *in situ* determination of the solar calibration constant, and the precision of the method—by testing a five-month dataset obtained from a Prede skyradiometer in Rome, Italy—was estimated to fall within 1%–2.5% depending on the wavelength for overhead sun (optical airmass = 1).'

Lines 106-108, Section 2.2: It seems that you are retrieving SKYNET AOD from two different methods. More detail on the differences in these methods needs to be provided.

Response: Following the reviewer's comment, the revised manuscript now states that "The SR-CEReS developed by Chiba University selected the input data for the ILP method more carefully than before, from the measurements taken in more than 1 month before and after the target day (to keep sufficient number of data points) using a stricter criterion of error in input data." Additionally, because the skyrad.pack version 5.0 is included in the SR-CEReS as the main program, it should be only one method. Because of this, we do not say that SR-CEReS has been improved over version 5.0. So we remove the comparison between the two SKYNET retrieved AOD and AERONET retrieved AOD. The comparison between SKYNET SR-CEReS-retrieved AOD and AERONET-retrieved AOD is shown in Fig.2. The sentences have modified in the revised manuscript. (Line 113-115)

'The SR-CEReS software developed by Chiba University selects the input data for the ILP method more carefully than before, from the measurements taken in more than 1 month before and after the target day (to keep sufficient number of data points) using a stricter criterion of error in input data.'

Lines 125-129, Section 2.2: However, this does not take into account the fact that AOD versus wavelength is not linear in logarithmic coordinates (see Eck et al. 1999). This is particularly true in Beijing since the fine mode particle size is often relatively large when AOD is high, and needs to be discussed.

Response: Following the reviewer's comment, the reference and the sentence' When AOD is high, the fine mode particle size is often relatively large, particularly in Beijing with high aerosol burdens' have added into the revised manuscript. When 440nm AOD>0.4, the simultaneous AEs (AE(440-870)>1.2)from SKYNET and AERONET have a little large RMS differences(i.e. ~0.05 etc.); However, the simultaneous AEs (AE(440-870)<0.8)from SKYNET and AERONET have small RMS differences(i.e. ~0.01 etc.). (Line 132-134)

'However, the AOD versus wavelength is not linear in logarithmic coordinates (Eck et al., 1999). When AOD is high, the fine-mode particle size is often relatively large, particularly in Beijing with high aerosol burdens.'

Line 138, Section 2.3: Explain why you chose 72 hours for back trajectories given that aerosol lifetime is typically 1 week (7 days).

Response: Because many studies focused on the backward trajectories by choosing 72 hours (Zheng et al., 2017a; Zheng et al., 2017b; Gui et al., 2016).

Zheng, Y., Kuang, X., Li, X., Sun, E., Zhao, D., Yang, D., Zhao, T., Che, H., Wang, Y., Zhao, H., Wang, H., Wang, D., Gui, K., An, L., Sun, T., Yu, J., Zhang, X., Yang, L., Chen, J., Xia, X. and Guo, Z.: Optical and radiative properties of aerosols during a severe haze episode over the North China Plain in December 2016, J. Meteorol. Res., 31(6), 1045–1061, doi:10.1007/s13351-017-7073-7, 2017a.

Zheng Y , Che H , Zhao T , et al. Aerosol optical properties observation and its relationship to meteorological conditions and emission during the Chinese National Day and Spring Festival holiday in Beijing[J]. Atmospheric Research, 2017b, 197:188-200.

Gui, K., Che, H., Chen, Q., An, L., Zeng, Z., Guo, Z., Zheng, Y., Wang, H., Wang, Y., Yu, J. and Zhang, X.: Aerosol optical properties based on ground and satellite retrievals during a serious haze episode in December 2015 over Beijing, Atmosphere (Basel)., 7(5), doi:10.3390/atmos7050070, 2016

Line 156, Section 3.1: AOD is not retrieved by AERONET, no inversion algorithm is used to determine AOD. It is measured from direct sun observations. Also, you should cite the reference of Giles et al. (2019) when discussing the V3 AOD data.

Response: The wrong description of AOD has corrected and the reference has been cited in the revised manuscript. (Line 167-170)

'The level-2.0 AOD from AERONET are used to compare with the AOD from SKYNET, while the level-1.5 data retrieved by the version-3 inversion algorithm from AERONET providing fully automatic cloud screening and instrument anomaly quality controls (Giles et al. 2019) are used to compare with the SSA, complex refractive index, and volume size distribution retrieved by SKYNET SR-CEReS.'

Line 162, Section 3.1: Please give the biases in units of AOD also (i.e. ~0.02 etc.).

Response: The RMSE, MBD, Correlation coefficient are given in the revised manuscript. (Line 175-176)

'The RMSE (root mean square error), defined as $\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\delta_{skynet,i} - \delta_{aeronet,i}\right)^2}$ at 500 nm, 670 nm, 870 nm and 1020 nm is 0.020, 0.020, 0.011 and 0.010, respectively.'

Lines 162-164, Section 3.1: The way this sentence is written it is impossible to tell which of the 2 different SKYNET AOD values you are discussing here.

Response: Sorry for misunderstanding of previous statements, now we only discuss the comparison of SKYNET SR-CEReS and AERONET AOD, and the new results are shown in the revised manuscript. (Line 171-181)

'Figure 2 shows the results of SKYNET AOD compared with AERONET AOD. Figures 2a–d show that the AOD retrieved from the AERONET sunphotometer, at all wavelengths, is systematically higher than that retrieved from the SKYNET skyradiometer, and the MBD (mean bias deviation), defined as $\mathrm{MBD} = \bar{\Delta} = \frac{1}{n}\sum_{i=1}^{n}(\delta_{skynet,i} - \delta_{aeronet,i})$ at 500 nm, 670 nm, 870 nm and 1020 nm is -0.014, -0.015, -0.008 and -0.006 respectively. The RMSE (root mean square error), defined as $\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\delta_{skynet,i} - \delta_{aeronet,i})^2}$ at 500 nm, 670 nm, 870 nm and 1020 nm is 0.020, 0.020, 0.011 and 0.010, respectively. The correlation coefficient of AOD between the SKYNET SR-CEReS retrieval and AERONET at each channel is larger than 0.996. These statistical parameters confirm that the two networks' instruments are highly consistent in their measurement of AOD. Importantly, the AOD from SKYNET at 670 nm correlates to the AOD at 675 nm from AERONET, which may lead to the relatively large differences. Additionally, the comparison of AOD at shorter wavelengths has larger biases than that at longer wavelengths.'

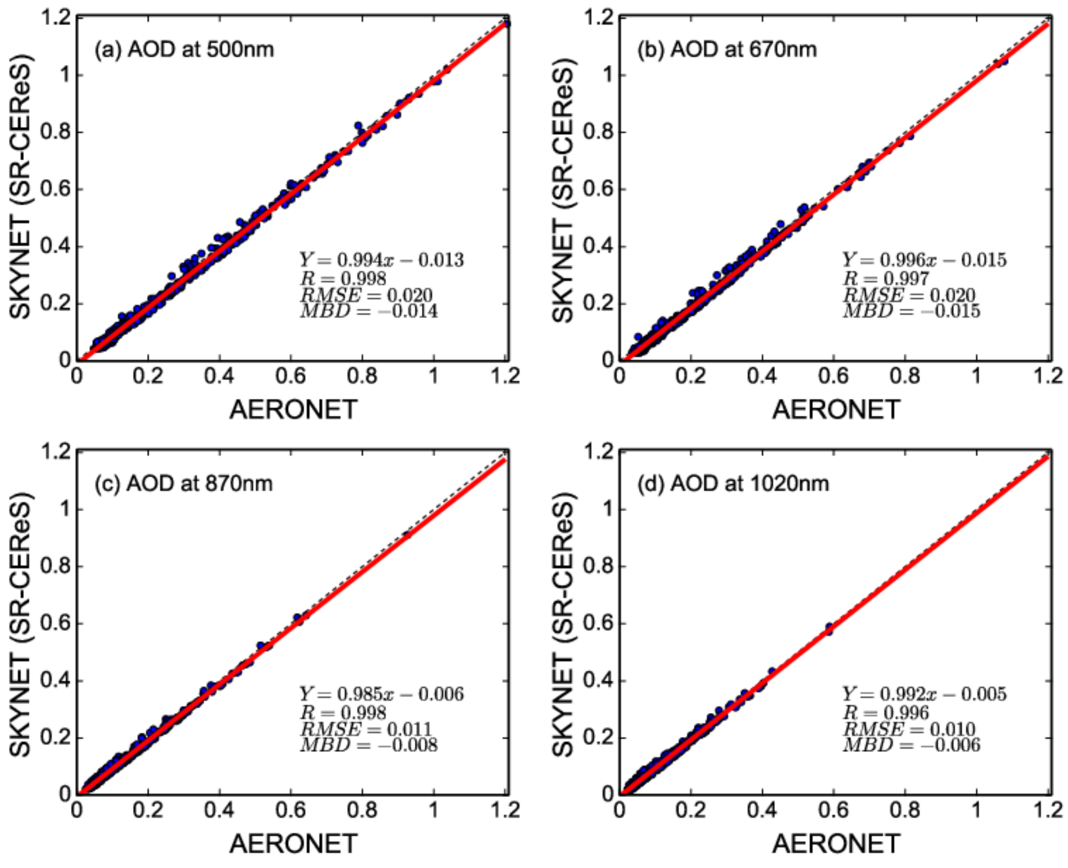


Figure 2: Comparison of SKYNET SR-CEReS–retrieved AOD with that from AERONET (within 1 minute) at 500, 670, 870 and 1020 nm over Beijing. The red solid line is the fitted linear regression curve.

Line 168, Section 3.1: Please give some specifics here about what is done to select data 'carefully' here.

Response: We think this sentence makes no sense here, so it has removed. Specifics is that the SR-CEReS selected the input data from the measurements taken in more than 1 month before and after the target day (to keep sufficient number of data points) using a stricter criterion of error in input data.

Line 170, Section 3.1: Please state in the text what is correlated in Figure 3, AERONET versus SKYNET from the SR-CEReS retrievals?

Response: The sentence has been modified in the revised manuscript. (Line 182)

'A comparison of Ångström exponent retrieved from SKYNET SR-CEReS and AERONET is shown in Fig. 3.'

Line 174, Section 3.1: It would be useful to know if the correlation increases for the data subset where AOD(440)>0.4, since the Angstrom Exponent is highly uncertain at low AOD.

Response: According to the advice, the correlation increases a lot for the data subset when AOD(440)>0.4. The new results are shown in Fig. 3. (Line 182-190)

'A comparison of Ångström exponent retrieved from SKYNET SR-CEReS and AERONET is shown in Fig. 3. Only data with AOD_{440nm}>0.4 are shown, since AE is highly uncertain at low values of AOD and the comparison result is bad (0.182-0.334 for all the wavelengths). Figure 3a-c show that the AE from AERONET is systematically lower than that from SKYNET SR-CEReS, the MBD of AE at 440-670 nm ($\alpha_{440-670nm}$), 440-870 nm ($\alpha_{440-870nm}$) and 500-870 nm ($\alpha_{500-870nm}$) is 0.063, 0.016 and 0.009; the RMSE at 440-670 nm, 440-870nm and 500-870 nm is 0.080, 0.042 and 0.048; the correlation coefficient at 440-670 nm, 440-870nm and 500-870 nm is 0.986, 0.992 and 0.990. Both the highest correlation coefficient of AE and the lowest RMSE of AE are at 440-870 nm. The simultaneous AE within one minute ($\alpha_{440-870nm}$>1.2) from SKYNET SR-CEReS and AERONET has large RMS differences about 0.060; However, the simultaneous AE ($\alpha_{440-870nm}$ <0.8) from SKYNET SR-CEReS and AERONET has small RMS differences about 0.013.'

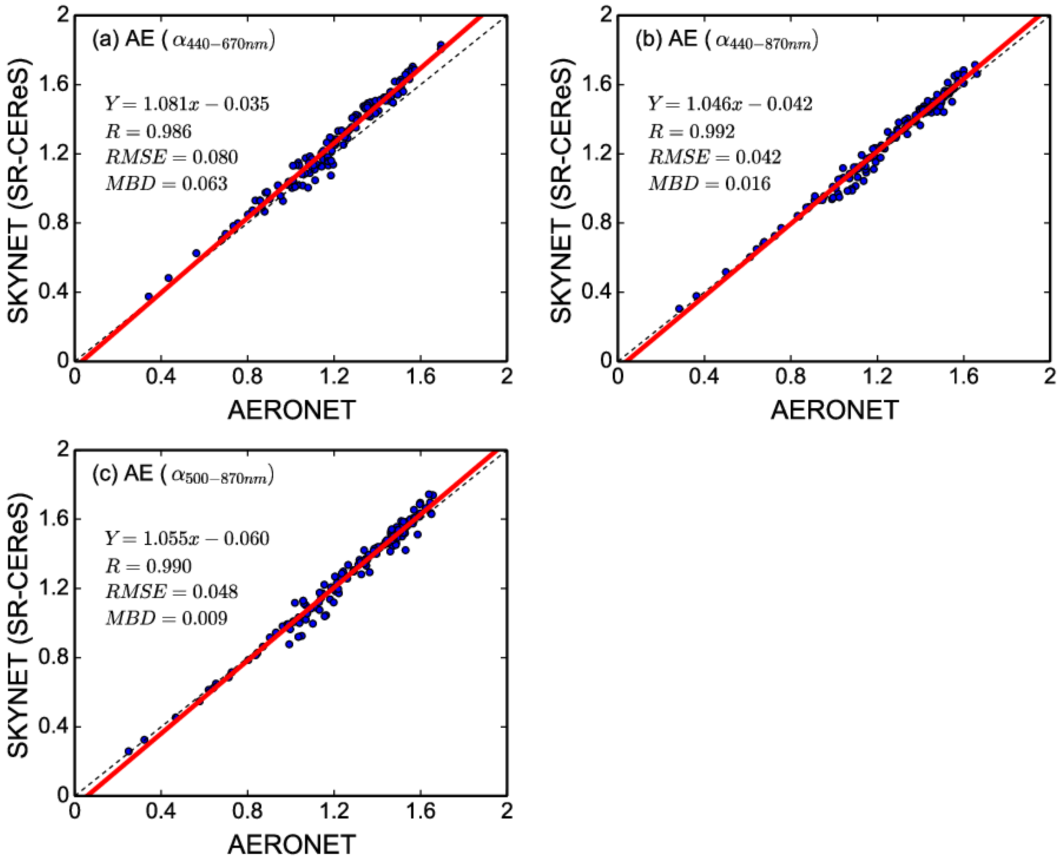


Figure 3: Comparison of SKYNET with AERONET Ångström exponent (within 1 minute) at 440–670 nm, 440–870 nm and 500–870 nm over Beijing. Only data with AOD > 0.4 are shown. The red solid line is the fitted linear regression curve.

Lines 179-180, Section 3.1: You should interpolate the SKYNET 400 nm and 500 nm SSA to 440 nm by linear interpolation in linear coordinates, before making comparisons to AERONET.

Response: According to the advice, the SKYNET 400 nm and 500 nm SSA are calculated by linear interpolation. The new results are shown in Fig. 4.

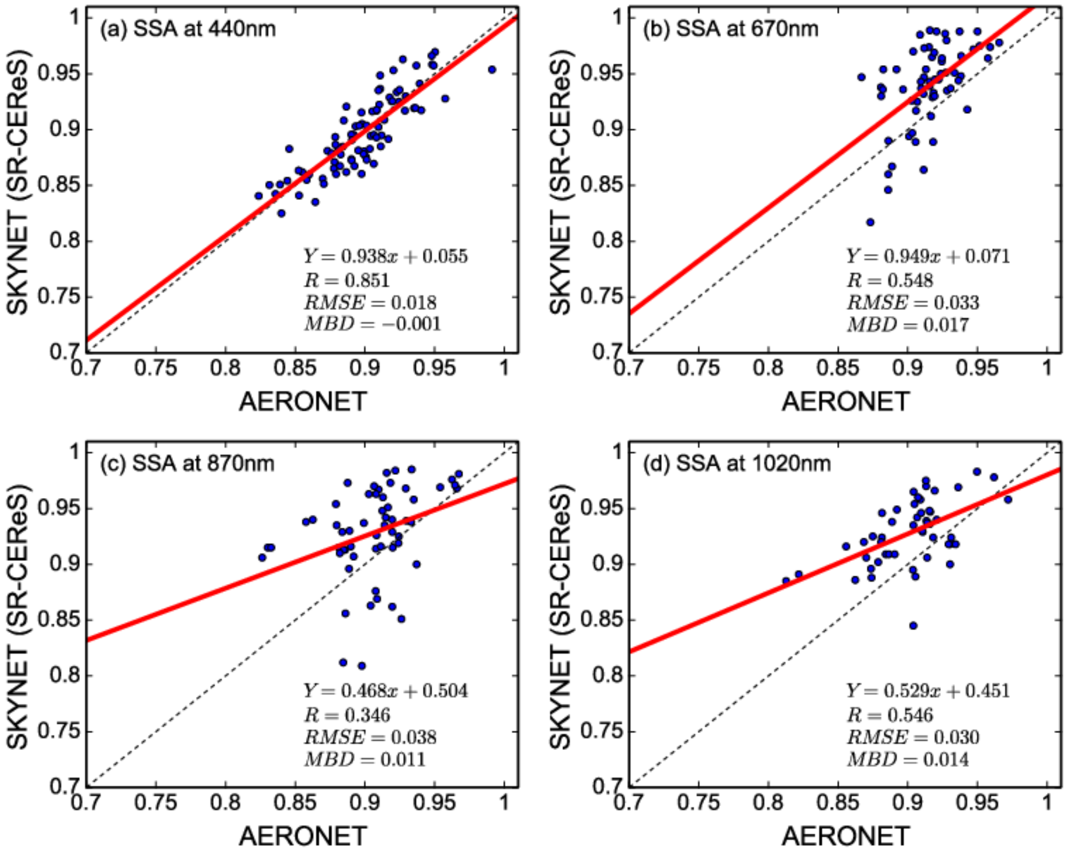


Figure 4: Comparison of SKYNET and AERONET SSA (within 3 minutes) at 440, 670, 870 and 1020 nm over Beijing. Only data with AOD > 0.4 are shown. The red solid line is the fitted linear regression curve.

Line 182, Section 3.1: Please also provide the bias in units of SSA (i.e. ~0.03 differences).

Response: The RMSE, MBD, Correlation coefficient are given in the revised manuscript. (Line 194-196)

'The correlation coefficients are 0.851, 0.548, 0.346 and 0.546 at 440 nm, 670 nm, 870 nm and 1020 nm, respectively. The MBD of SSA at each channel is -0.001, 0.017, 0.011 and 0.014, which means the SSA from the SKYNET skyradiometer is almost larger than that from the AERONET sunphotometer. The RMSE of SSA at each channel is 0.018, 0.033, 0.038 and 0.030.'

Line 183, Section 3.1: Please note here that the SKYNET SSA retrievals hit the saturation value of 1.0 in a significant number of cases while AERONET SSA does not.

Response: The values of SKYNET SR-CEReS lying on the 1.0 axis are due to by-default values in case of good retrievals and should perhaps be removed. The new results are shown in Fig. 4.

Line 188, Section 3.1: You need to define SA here and explain briefly how it relates to influencing the magnitude of sky radiances.

Response: SA has been defined here and the effect of the calibration constant and surface albedo have been given in the revised manuscript. (Line 202-204)

'The factors affecting the inconsistent SSA between SKYNET and AERONET were studied by

Khatri et al. (2016), who stated that underestimating the calibration constant for sky radiance is the most likely reason for the high SSA at each channel in SKYNET, and surface albedo (SA) is regarded as a secondary effect of SSA. The effects of the calibration constant are 41%, 53% and 54% at 675 nm, 870 nm and 1020 nm, however, the effect of surface albedo ranges from ~7 to 15% in terms of absolute value (Khatri et al., 2016).'

Lines 198-199, Section 3.1: Please make it clearer that these constant values of surface reflectance for all sites is a very crude assumption. Also state in the text that AERONET uses geographically and seasonally varying surface reflectance values that are much more robust.

Response: Clearer description and the statement that AERONET SA is better than SKYNET SA have shown in the revised manuscript. (Line 213-215)

'These constant values of surface reflectance for all sites is a very crude assumption. AERONET uses geographically and seasonally varying surface reflectance values that are more robust than SKYNET constant values of surface reflectance.'

Lines 215-217, Section 3.1: This is obvious, and you should mention that the imaginary refractive index is the retrieved parameter and that SSA is derived from this information along with the size distribution and the real refractive index.

Response: It has mentioned in the sentence of the revised manuscript. (Line 234-236)

'The imaginary refractive index is the retrieved parameter and that SSA is derived from this information along with the size distribution and the real refractive index.'

Lines 225-227, Section 3.1: It would be useful if you provided some comparisons of volume size distributions of fine mode dominated (AE(440-870)>1.2) and also coarse mode dominated cases (AE<0.6).

Response: Thanks for the advice, following the reviewer's comment, the revised manuscript now modifies the comparison of volume size distribution between AERONET and SKYNET. (Line 247-280)

'Comparisons of the volume size distribution of fine mode dominated ($\alpha_{440-870nm}$>1.2) and coarse mode dominated ($\alpha_{440-870nm}$<0.6) between AERONET and SKYNET are shown in Fig. 7, wherein only those data observed within 5 minutes of each other were considered as simultaneous. The volume of aerosol for an air column of unit cross section is used to express the columnar volume spectrum ($\mathrm{dV/dlnr}$), and the radius is in logarithmic form (Nakajima et al., 1996). There are differences in the assumptions of size distribution between the SKYNET and AERONET retrieval algorithms. The volume at each rated radius is calculated by averaging the values at that radius for both the SKYNET skyradiometer and the AERONET sunphotometer. However, the number of rated radii for SKYNET and AERONET is 20 and 22, respectively, meaning 20 rated radii (0.012, 0.018, 0.026, 0.038, 0.055, 0.081, 0.118, 0.173, 0.253, 0.370, 0.541, 0.791, 1.156, 1.691, 2.473, 3.617, 5.289, 7.734, 11.310 and 16.540 μm) are used to retrieve the volume size distribution for SKYNET and 22 rated radii (0.050, 0.066, 0.086, 0.113, 0.148, 0.194, 0.255, 0.335, 0.439, 0.576, 0.756, 0.992, 1.301, 1.708, 2.241, 2.940, 3.857, 5.061, 6.641, 8.713, 11.432 and 15.000μm) are used to retrieve the volume size distribution for AERONET. As is shown in Fig. 7a, the size distribution patterns of fine mode dominated from SKYNET and AERONET are both bimodal, which is typical, but the peak volumes bear some differences. Specifically, the two peak volumes from the SKYNET skyradiometer are at the radii of 0.173 μm and 5.289 μm, with columnar volume concentrations of 0.060 and 0.093 $\mu m^3/\mu m^2$; whereas, those from the AERONET sunphotometer are at radii of 0.148 μm and 3.857μm, with columnar volume concentrations of 0.063 and 0.075 $\mu m^3/\mu m^2$. From Fig. 7b we can see that, the size distribution patterns of coarse mode dominated from SKYNET and AERONET both show a bimodal pattern. The two peak volumes from the SKYNET skyradiometer are at the radii of 0.081 μm and 3.617 μm, with columnar volume concentrations of 0.075 and 0.632 $\mu m^3/\mu m^2$; whereas, those from the AERONET sunphotometer are at radii of 0.086 μm and 3.857μm, with columnar volume concentrations of 0.092 and 0.561 $\mu m^3/\mu m^2$. The significant difference between Fig. 7a and Fig. 7b is that the coarse-mode volume concentration in coarse mode dominated condition is much larger than that in fine mode dominated condition. One can see is that the coarse-mode volume concentration of SKYNET is larger than that of AERONET on average, whereas, in contrast, the fine-mode volume of SKYNET is smaller than that of AERONET on average. The SSA is a ratio that describes the scattering ability of aerosol particles and, generally, coarse-mode particles have a larger scattering ability, meaning the SSA will be larger when there are many coarse-mode particles. The difference in volume size distribution between SKYNET and AERONET might be one reason why the SSA retrieved from SKYNET is larger than that retrieved from AERONET. It can be clearly seen that the deviations of the columnar volume concentrations around the peak volumes are larger than for other volumes, which is the same for both the SKYNET skyradiometer and the AERONET sunphotometer. However, the deviations for the volume of fine-mode particles retrieved from AERONET are larger than those of SKYNET in most cases, which is due to changes in fine mode radius from low AOD to high AOD conditions and also from dry to humid conditions; whereas, for the volume of coarse-mode particles, the deviations are larger for SKYNET than AERONET. From Fig. 7 we can see that the columnar volume spectrum retrieved from AERONET is nearly 0 $\mu m^3/\mu m^2$ at the radii less than 0.050 μm and more than 15.000 μm . This is by definition since these are the limits of the size distribution for AERONET and there is a strong constraint in the AERONET retrieval that results in near zero values at the limits.'

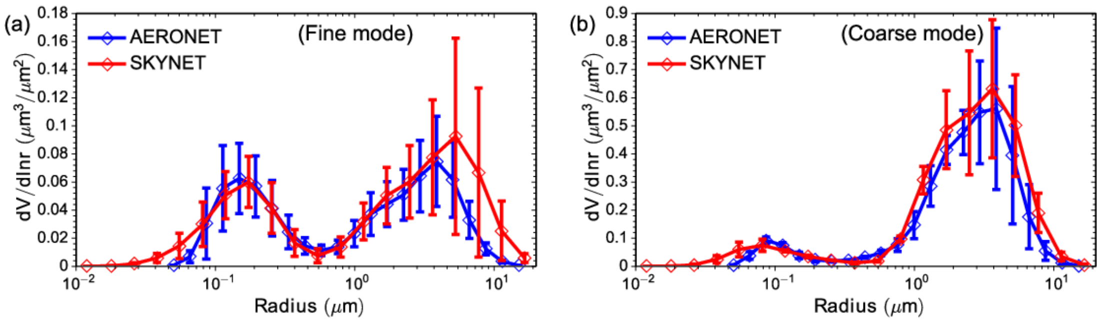


Figure 7: Comparison of SKYNET- and AERONET-retrieved volume size distributions (within 5 minutes) of (a) fine mode dominated (AE(440-870)>1.2) and (b) coarse mode dominated cases (AE(440-870)<0.6) over Beijing.

Line 238, Section 3.1: These are typically called volume concentrations not volume spectra.

Response: Following the reviewer's comment, volume concentrations has applied in the revised manuscript. (Line 260)

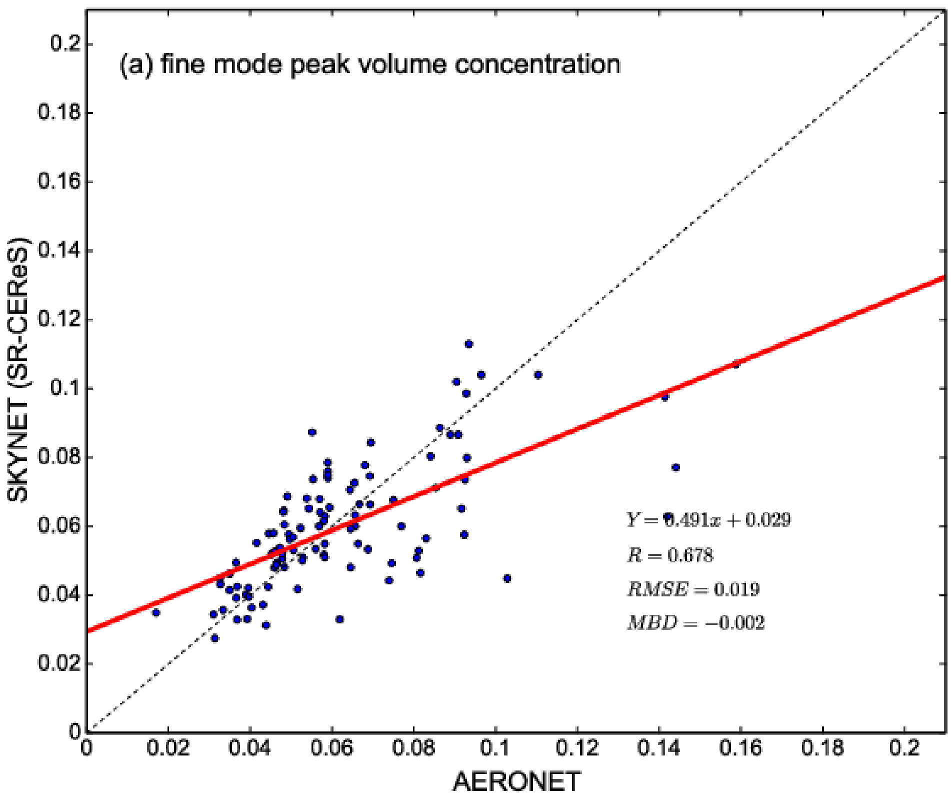
‘Specifically, the two peak volumes from the SKYNET skyradiometer are at the radii of 0.173 μm and 5.289 μm, with columnar volume concentrations of 0.060 and 0.093 $\mu m^3/\mu m^2$;’

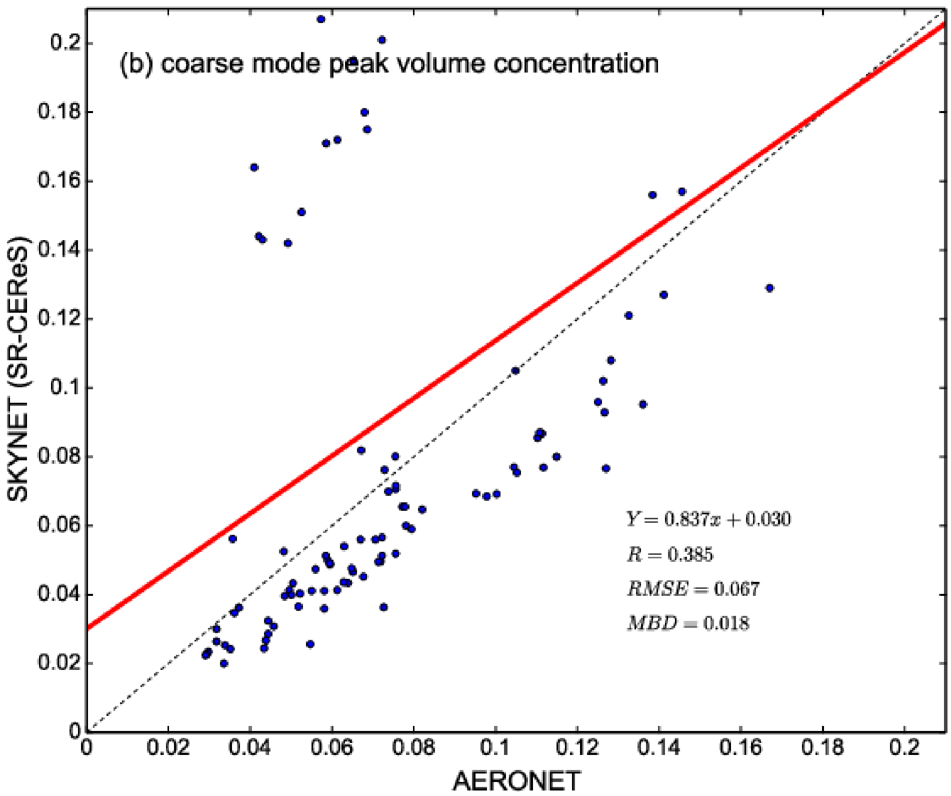
Line 247-251, Section 3.1: I think your earlier analysis of the effects of surface albedo and solid view angle are the more likely reasons for differences in SSA and IM between the AERONET and SKYNET retrievals. I suggest removing this sentence.

Response: Following the reviewer's comment, the revised manuscript now remove this sentence. (Line 272)

Line 251-252, Section 3.1: Some of this fine mode peak volume concentration variance is due to changes in fine mode radius from low AOD to high AOD conditions and also from dry to humid conditions. Showing one average size distribution is a very poor way to compare these two products. A scatterplot of SKYNET versus AERONET would be much more informative.

Response: The reason for the bias of the fine-mode peak volume concentration adds in the revised manuscript. (Line 274-276) Based on the comparisons of volume size distributions of fine mode dominated (AE(440-870)>1.2), scatterplots of SKYNET versus AERONET in fine mode peak (a) and coarse mode peak (b) volume concentration is shown. We can see that the correlation coefficient, RMSE and MBD of fine-mode peak volume concentration are better than those of coarse-mode peak volume concentration.





‘However, the deviations for the volume of fine-mode particles retrieved from AERONET are larger than those of SKYNET in most cases, which is due to changes in fine mode radius from low AOD to high AOD conditions and also from dry to humid conditions;’

Line 254-255, Section 3.1: This is by definition since these are the limits of the size distribution for AERONET and there is a strong constraint in the AERONET retrieval that results in near zero values at the limits.

Response: Following the reviewer's comment, the revised manuscript now modifies this sentence. (Line 279-280)

‘This is by definition since these are the limits of the size distribution for AERONET and there is a strong constraint in the AERONET retrieval that results in near zero values at the limits.’

Line 260-265, Section 3.2: Please make it clear in the figure captions that these frequency distributions are for the SKYNET retrievals only.

Response: Both AERONET and SKYNET retrievals are used to analyze frequency distributions. The clear figure captions show in the Fig. 8 and Fig. 9 in the revised manuscript. (Line 281)

‘3.2 Frequency distribution of SKYNET-retrieved and AERONET-retrieved AOPs in Beijing’

Line 266-271, Section 3.2: Are these frequency distributions from multi-year data? Or just one year for each season? The AERONET data base would provide much more robust statistics for fall versus winter than just these 2 seasons of data from SKYNET. I suggest remaking the frequency distribution plots from multi-year AERONET data in order to have a more robust seasonal comparison, including for all four seasons.

Response: Following the reviewer's comment, the revised manuscript gives the frequency distribution plots from AERONET data and SKYNET data in order to make the comparisons. The new description for Section 3.2 using the data from September 2016 to January 2019. To ensure the integrity of the comparison, we add the SKYNET data for spring and summer. However, the SKYNET Severely lacks the summer data, so there are large errors in this season. (Section 3.2)

'Figure 8 and figure 9 show the frequency distribution of SKYNET-retrieved and AERONET-retrieved AOPs in Beijing, respectively. The study period is from September 2016 to January 2019, but the SKYNET dataset is seriously lack of summer data (Only 1 June to 5 June 2017). The frequency distribution of SKYNET AOD values at 440 nm is shown in Fig. 8a. The bin interval for the AOD is 0.1. The frequency distribution of AOD values within the range 0.0-0.4 are about 33.85%, 29.36%, 49.41% and 70.83% of all values in spring, summer, autumn and winter, respectively. The frequency distribution of AERONET AOD values at 440 nm shown in Fig. 9a account for about 36.12%, 41.51%, 61.87% and 68.27% of all values in spring, summer, autumn and winter, respectively. From the frequency histograms of SKYNET AOD values at 440 nm we can see a typical bimodal pattern with two peak ranges of AOD at 0.1–0.2 and 0.4-0.5 in winter and a single pattern with a peak range of AERONET AOD at 0.1-0.2 in winter. The mean values of SKYNET AOD are about 0.66, 0.56, 0.49 and 0.30 in spring, summer, autumn and winter, respectively. The mean AERONET AOD in each season is about 0.67, 0.79, 0.46 and 0.39. During the study period, we can see that relatively high AOD values often occur in spring and summer. Frequent dust events during spring lead to high aerosol burden and the reason for high AOD levels in summer might be the hygroscopic growth of water-soluble aerosols. The frequent cold air with strong winds may lead to the lower AOD values in winter because they can accelerate the diffusion of pollutants (Giavis et al., 2005).

The frequency distribution of SKYNET and AERONET Ångström exponent at 440-870 nm is shown in Fig. 8b and Fig. 9b. The bin interval is 0.1. The frequency distributions of SKYNET Ångström exponent values between 0.0 and 0.6 account for about 12.18%, 10.26%, 12.06% and 6.86% of all values in spring, summer, autumn and winter, respectively. The frequency distributions of AERONET Ångström exponent values within the range of 0.0 to 0.6 are about 10.06%, 3.26%, 6.98% and 8.08% of all values in spring, summer, autumn and winter, respectively. Meanwhile, the frequency distributions of SKYNET Ångström exponent values larger than 1.2 are about 35.44%, 10.68%, 38.38% and 64.41% of all values in spring, summer, autumn and winter, respectively. In term of AERONET, Ångström exponent values larger than 1.2 account for near 28.01%, 68.84%, 47.86% and 40.71% of all values in spring, summer, autumn and winter, respectively. It can be clearly seen that larger aerosol particles often present in spring and finer particles usually exist in summer and winter.

The SSA frequency histogram in Fig. 8c and Fig. 9c show various ranges of SKYNET and AERONET SSA for the four seasons. The bin interval for the SSA is 0.01. The frequency distributions of SSA (>0.95) account for 17.64%, 6.17%, 23.82%, 6.87% of all SKYNET values and 14.26%, 68.56%, 20.85%, 3.44% of all AERONET readings in spring, summer, autumn and winter, respectively, suggesting that there are more scattering aerosol particles in summer and autumn while more absorbing aerosol particles such as black carbon are in winter (Li et al., 2019). The hygroscopic growth of aerosol can enhance scattering ability, which leads to the high SSA level in summer.

The volume size distribution of aerosol plays a major role in observations and simulations of radiative forcing (Dusek et al., 2006). From Fig. 8d, we can see that the volume size distributions for four seasons show a typical bimodal pattern, the coarse-mode volume concentrations are larger than the fine-mode volume concentrations. The coarse-mode volume concentration is largest in spring, follow by autumn and winter (not consider summer). As for AERONET volume size distribution in Fig. 9d, it can be seen that the volume size distributions for each season shows a typical bimodal pattern. The coarse-mode volume concentrations are larger than the fine-mode volume concentrations in spring but the result is just opposite to summer.

According to the frequency distributions of SKYNET and AERONET retrieved AOPs over Beijing for the study period, we can see that the average AOD value for the whole of spring and summer is larger than that for the whole of autumn and winter. Ångström exponent values are higher in winter and smaller in spring, and the results indicate that the size of aerosol particles are larger in spring and smaller in winter. Vertical air turbulence in summer is stronger than that in other seasons, and a greater number of particles such as floating dust transport into the upper air. Hygroscopic growth of water-soluble aerosol frequently occur in summer, due to more precipitation in summer. Aerosol particles combine with water vapor to become larger and ultimately improve the aerosol scattering ability (Yan et al., 2009). Dust events lead to more coarse-mode particles in spring and more precipitation removes the coarse-mode particles in summer, which can be confirmed in the volume size distribution.'

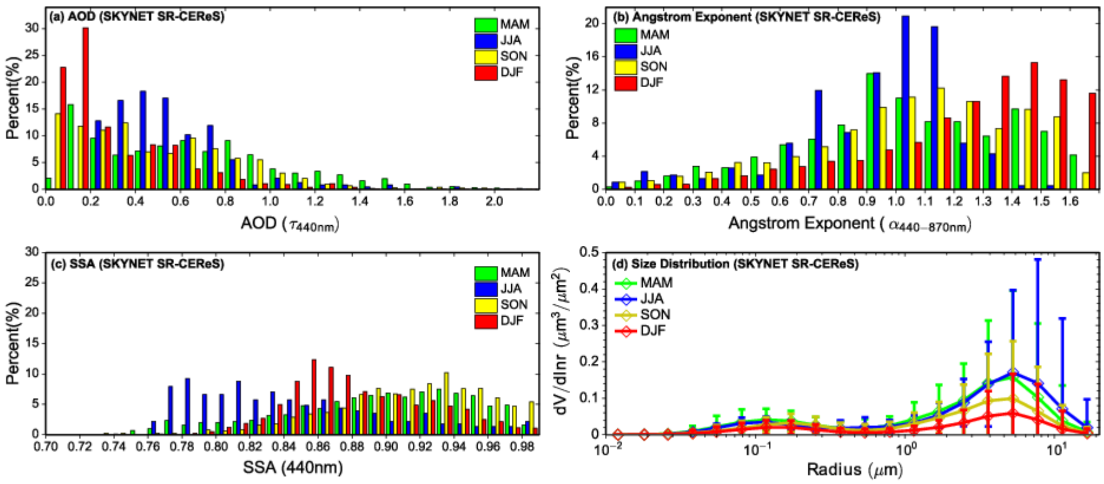


Figure 8: Frequency distribution of SKYNET SR-CEReS-retrieved (a) AOD at 440 nm, (b) Ångström exponent at 440–870 nm, (c) SSA at 440 nm, and (d) volume size distribution in spring (March-April-May, MAM), summer (June-July-August, JJA), autumn (September–October–November, SON) and winter (December–January–February, DJF) over Beijing for the period from September 2016 to January 2019.

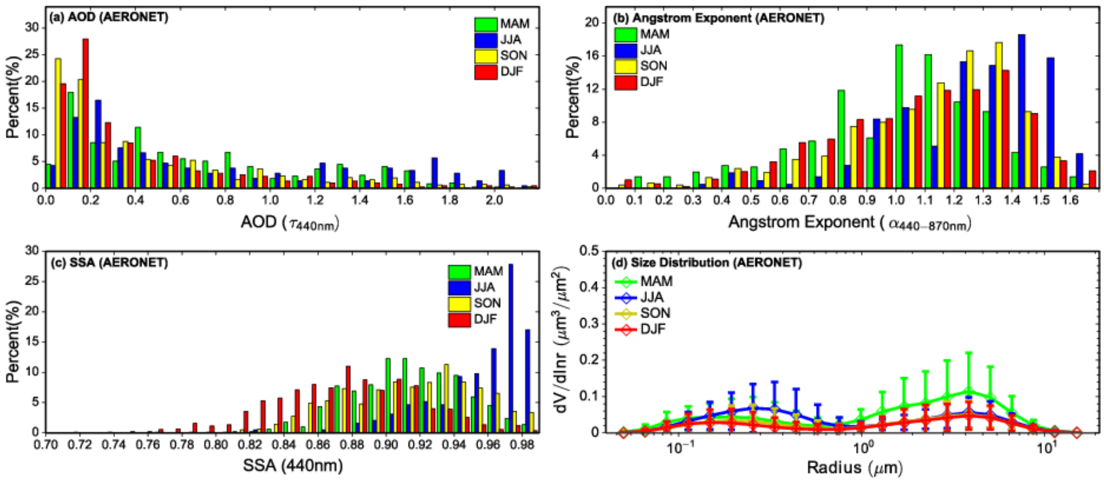


Figure 9: Frequency distribution of AERONET-retrieved (a) AOD at 440 nm, (b) Ångström exponent at 440–870 nm, (c) SSA at 440 nm, and (d) volume size distribution in spring (March-April-May, MAM), summer (June-July-August, JJA), autumn (September–October–November, SON) and winter (December–January–February, DJF) over Beijing for the period from September 2016 to January 2019.

Line 280-281, Section 3.2: Similar comment as above: Since the study period of the SKYNET data is so limited it seems that you cannot make any general statements about fall versus winter aerosol properties unless you redo this climatological analysis with AERONET data and expand it to all 4 seasons.

Response: The revised manuscript has removed the wrong description, The AERONET dataset and new SKYNET data are used for the Section 3.2. (Section 3.2)

Line 284-286, Section 3.2: It is well known that the major dust season in this region is spring and you ignore this since the SKYNET data set is so limited.

Response: Yes, I also think so, the revised manuscript has removed the wrong description, AERONET data and new SKYNET data are used for the Section 3.2. (Section 3.2)

Line 288-289, Section 3.2: Hygroscopic particle growth leads to larger fine mode particles, not a shift from fine to coarse mode, as this sentence suggests.

Response: The sentence has removed in the revised manuscript. (Section 3.2)

Line 292, Section 3.3: Figure 9 x-axis labels are wrong, it is not hours but days, from Dec 27 through Jan 9, 2017.

Response: We have replace 'hours' with 'days' in the revised manuscript. (Fig. 10)

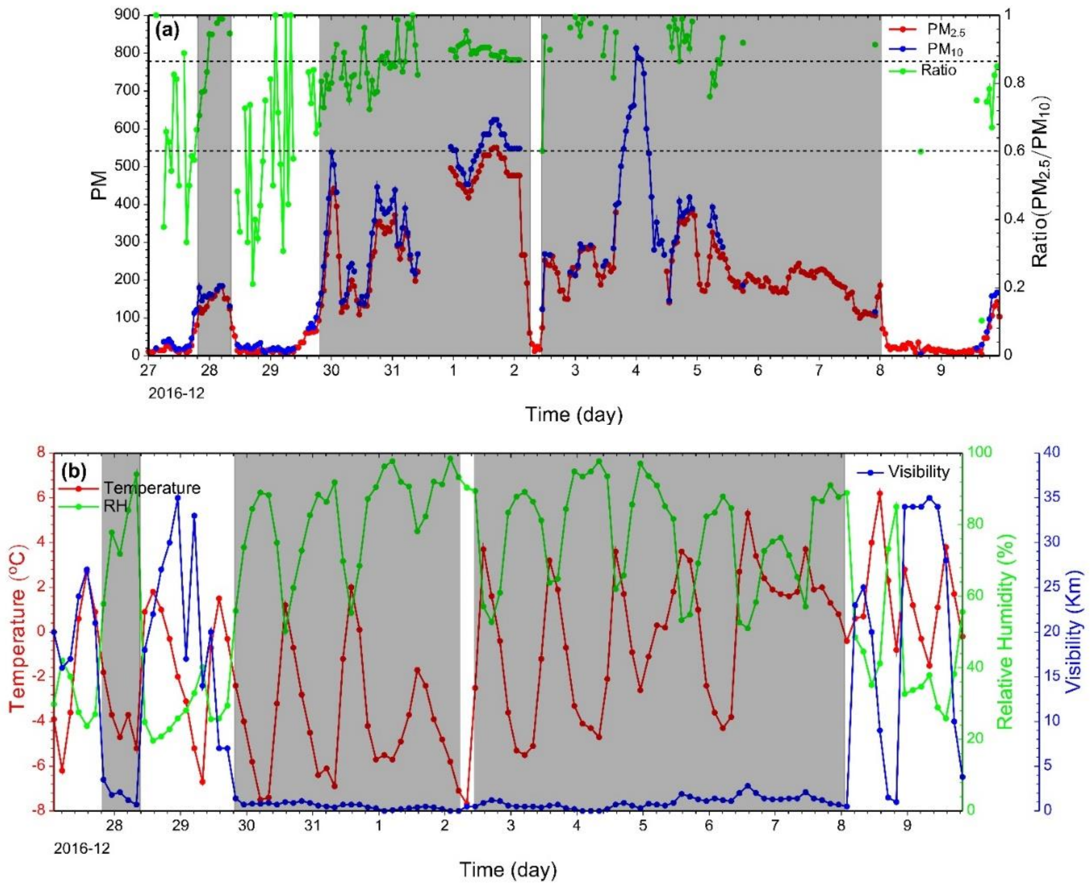


Figure 10: Temporal variations of (a) $PM_{2.5}$, PM_{10}, and their ratio ($PM_{2.5}/PM_{10}$), and (b) meteorological data including temperature (℃), RH (%), and visibility (km), from 27 December 2016 to 9 January 2017. The shaded parts represent the pollution periods.

Line 296, Section 3.3: Define the ratio here in the text as PM2.5/PM10.

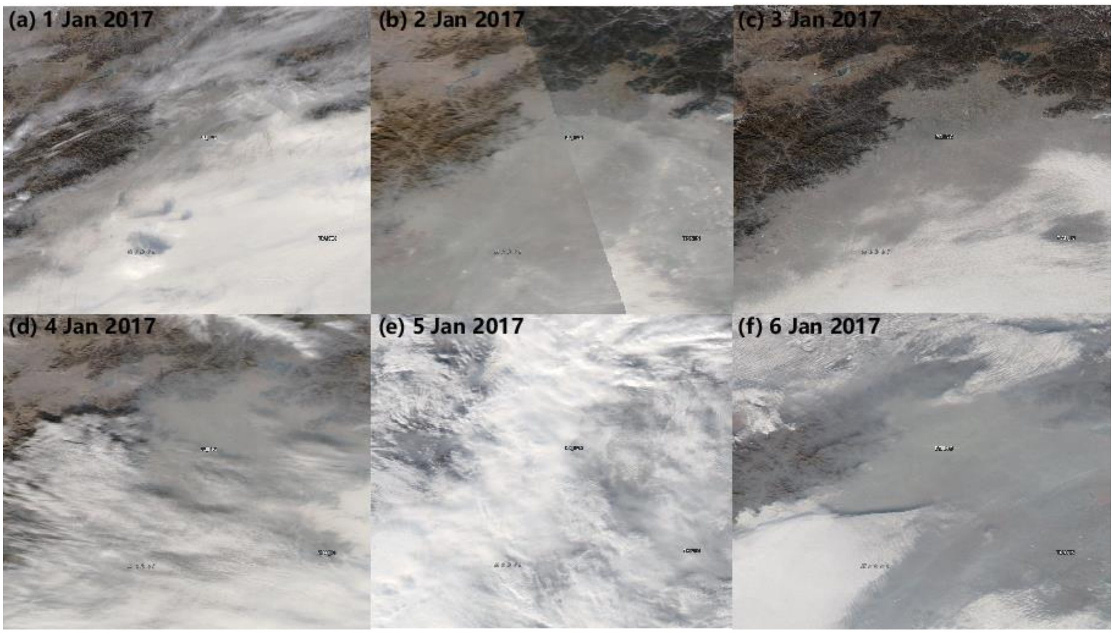
Response: We have defined the ratio here in the revised manuscript. (Line 333)

'During the non-pollution periods, the ratios ($PM_{2.5}$ / PM_{10}) change greatly, while those in the pollution periods change little.'

Line 302, Section 3.3: You should also discuss the large amount of fog present from Jan 1 - Jan 5, 2017 in the region around Beijing (MODIS images show this), and the high cloud cover amount on Jan 4, 2017. Li et al. (2014) in Atmospheric Environment analyze the high AOD and PM associated with fog in Beijing in January of 2013. Fog may be associated with large secondary production of aerosols in the region. Also, Eck et al., 2018 show the association of high cloud amount in Beijing with high AOD levels, likely due to humidification growth of fine particles.

Response: The discussion about the fog and the high cloud has added in the revised manuscript. The MODIS images could put in the supplement. (Line 342-346)

'The large amount of fog can be seen from 1 January to 6 January 2017 in the region around Beijing from Aqua/MODIS images (see Supplement Fig. S3). Fog may be associated with large secondary production of aerosols in this region, which leads to heavy pollution (Li et al., 2014). In addition, the high cloud cover amount on 4 January and 5 January 2017. The association of high cloud amount in Beijing with high AOD levels, likely due to humidification growth of fine particles (Eck et al., 2018).'



Line 319-320, Section 3.3: You show a PM2.5 value in Figure 10 for Jan 4 but in Figure 9 you only show the PM10 value for that day. This inconsistency needs to be explained or else corrected.

Response: In Fig. 9 (in the revised manuscript is Fig. 10), the PM data is hourly data, but for Fig. 10 (in the revised manuscript is Fig. 11), the PM data is daily data. It is important that the much large PM values may be missing values. When we described the PM_{10} reaches 813$\mu g/m^3$, it is hourly data. Unlucky, the $PM_{2.5}$ value is missing value. To describe more accurately, we add 'Instantaneous' before the 'value'. (Line 361)

'This would have been conducive to the accumulation of pollutants and, indeed, the Instantaneous value of PM_{10} reaches 813$\mu g/m^3$'

Line 371, Section 3.3: The AOD levels are too low on the clean day to have reasonably accurate SSA retrievals. You should not even discuss such SSA values that would have very large uncertainties (~0.10).

Response: It is true that the SSA is not very accurate when AOD is too low, so we remove the description about it. In the revised manuscript, we compare the AERONET and SKYNET Instantaneous values in the different weather conditions. (Line 411-419)

'A comparison among the daily variations in SKYNET and AERONET SSA at 440 nm on clean day (27 December 2016), light-pollution condition (2 January 2017) and heavy-pollution condition (4 January 2017) is depicted in Fig. 12b. We can find that the SSA of SKYNET has much more data than AERONET so that it can reflect the variation of one day in more detail. Because the number of daily measurements of sky radiance by the SKYNET skyradiometer was more than that of the AERONET sunphotometer, and thus it is an advantage for SKYNET to use SSA values to analyze the daily variation. The newest AERONET instruments now take hybrid scans hourly that providing more frequent retrievals throughout the entire day, which can make up the defect. The RMSE of SSA within 10 minutes between SKYNET and AERONET are 0.022, 0.046 and 0.020 on the clean day (27 December 2016), light-pollution condition (2 January 2017) and heavy-pollution condition (4 January 2017), respectively. The biases of SSA are lower when AOD is high.'

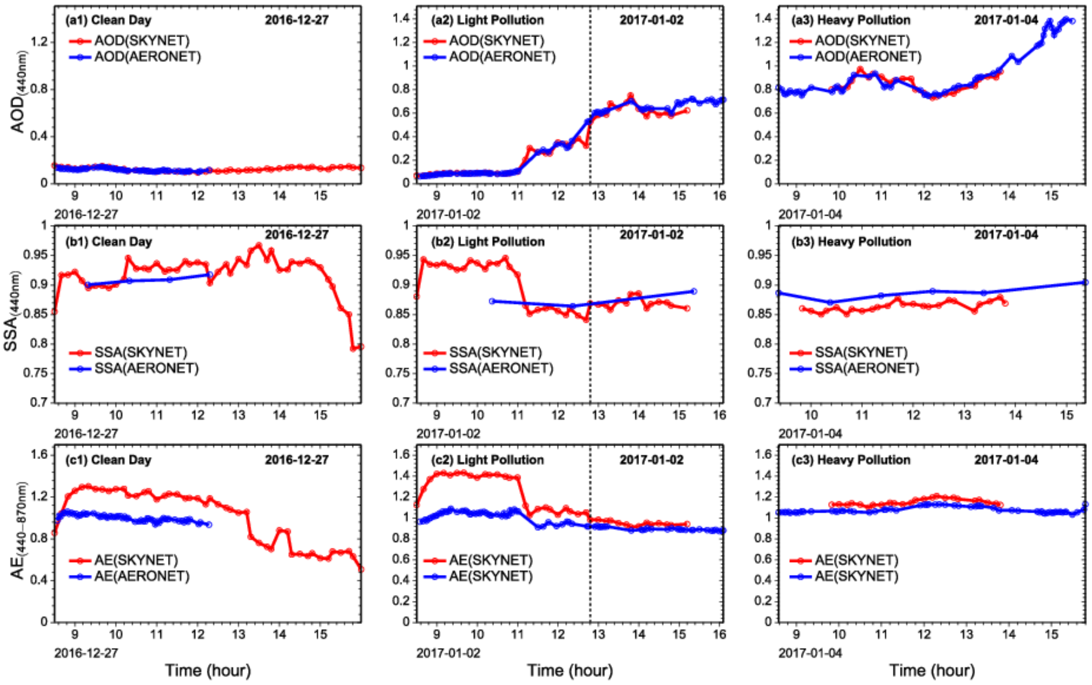


Figure 12: Temporal variation of (a) AOD, (b) SSA, and (c) Ångström exponent from the SKYNET skyradiometer and AERONET sunphotometer under (a1, b1, c1) clean, (a2, b2, c2) light pollution, and (a3, b3, c3) heavy pollution weather conditions in Beijing on 27 December 2016, 2 January, and 4 January 2017, respectively.

Line 391-392, Section 3.3: Please explain the trajectory # 1 and #2 as shown in the Figure 12.

Response: Detail description about the trajectories, the WPSCF and the WCWT on 27 December 2016 has added in the revised manuscript. (Line 439-446)

'Trajectories during 27 December 2016 converge into two clusters. Cluster 1 contributes a proportion of 40.00%, which originated from the northern edge of Xinjiang Province at an altitude near 4000 m, passing through Mongolia and Inner Mongolia, Hebei Province, and traveling eastwards to the Beijing region. Cluster 2 contribute 60.00%, the airmass was originally from Mongolia at an altitude about 3500 m, and the transmission path is similar to the Cluster 1. The WPSCF result indirectly reflects the impact of local emissions on the concentration of $PM_{2.5}$ in Beijing. There is no high-value regions (>0.6) in the figure because it is very clean in Beijng on 27 December 2016. The WCWT method can reflect the distribution of the concentration of $PM_{2.5}$ in the transmission path to Beijing. We can see that no high-vales regions (>75 $\mu g/m^3$) appear in the figure.
'

Line 405, Section 3.3: All 3 days show 2 clusters of trajectories although the differences in these are not explained. Are they from different altitudes?

Response: All 3 days show two clusters of trajectories but they are different in altitudes. From Fig. 12(1) (in the revised manuscript is Fig. 13), the different colors represent different altitudes.

And the description of the cluster`s original altitudes has given in the paper. (Section 3.3.3)

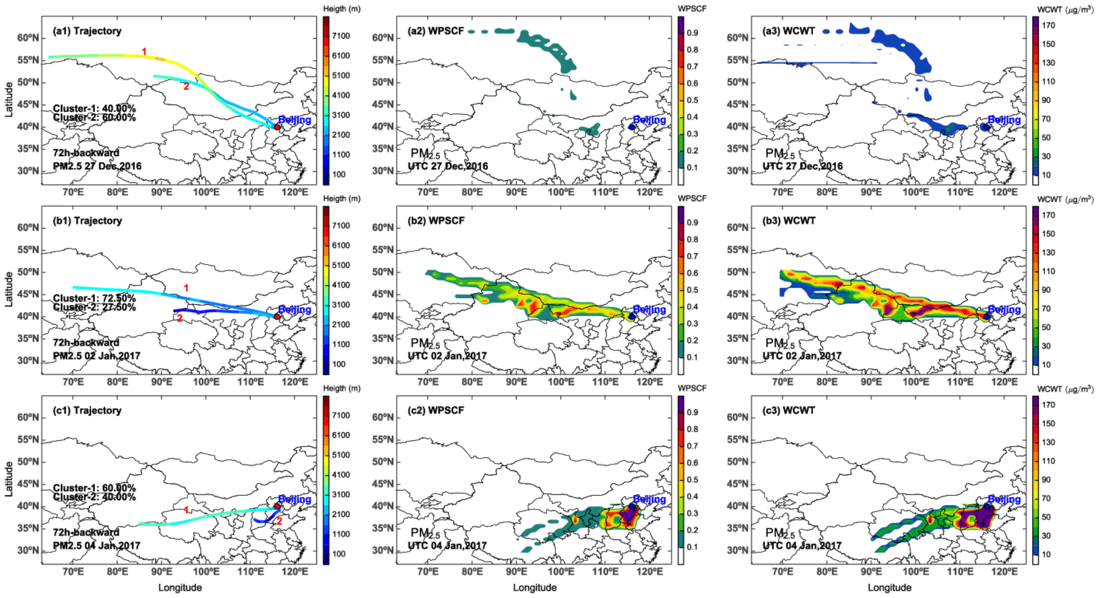


Figure 13: Mean 72-hour backward trajectories of each trajectory cluster and spatial distribution of WPSCF and WCWT values for $PM_{2.5}$ in Beijing during (a) 27 December 2016, (b) 2 January 2017, and (c) 4 January 2017.

Line 420, Section 4: Add 'of absorption ' here, after 'weakening'.

Response: We have added 'of absorption' after ' weakening'. (Line 225)

'the effect of the SVA on SSA manifests as a weakening of absorption'

Line 425-426, Section 4: This may be true for past data sets, but the newest AERONET instruments now take hybrid scans hourly that provide more frequent retrievals throughout the entire day.

Response: Yeah, the revised manuscript states that 'The newest AERONET instruments now take hybrid scans hourly that providing more frequent retrievals throughout the entire day, which can make up the defect.'. (Line 416-417)

'The newest AERONET instruments now take hybrid scans hourly that providing more frequent retrievals throughout the entire day, which can make up the defect.'

Line 427-428, Section 4: This sentence does not make any sense in the context of this paragraph and therefore should be removed.

Response: The sentence has removed in the revised manuscript.

Line 435-438, Section 5: In addition to the correlation coefficient is it import to also provide the rms differences and the average bias for the AOD and AE plus refractive indices (both real and imaginary) comparisons.

Response: The correlation coefficient, RMSE and MBD have added and the comparisons of other AOPs are given in the revised manuscript. (Line 474-484)

'Owing to the more careful selection of input data for the ILP method than before, the AOD from SKYNET retrieved by the SR-CEReS software are highly consistent with those from

AEROENT. The AOD between SKYNET and AERONET within 1 minute compares very well (0.010-0.020 for all the wavelengths), with smaller deviation at long wavelengths (870 nm and 1020 nm), the correlation coefficient between the SR-CEReS-retrieved SKYNET and AERONET AOD is larger than 0.996 at each wavelength. The RMSE of Ångström exponent (when AOD_{440nm}>0.4) is 0.080, 0.042 and 0.048 at 440–670nm, 440–870nm and 500–870nm, respectively, and the correlation coefficient is 0.986, 0.992 and 0.990 at each channel. The RMSE of SSA between SKYNET and AERONET within 3 minutes is 0.018, 0.040, 0.044 and 0.042 at 400, 500, 670, 870 and 1020 nm, respectively, with higher correlation coefficient (0.851) at 440 nm. The real and imaginary parts of the refractive index show deviations of 0.031-0.055 and 0.003-0.005 respectively for all the wavelengths. The highest correlation coefficient of the real part of the complex refractive index is 0.678, at the channel of 870 nm and for the imaginary part of the complex refractive index is 0.850 at 440 nm.'

Line 454-455, Section 5: It was never explained why only autumn and winter were analyzed, and the other 2 seasons ignored in this paper.

Response: This is due to the lack of summer data for SKYNET, so we only compare autumn and winter. However, in the revised manuscript, we compare the AERONET and SKYNET data in four seasons, though the summer result is not good.

Line 462, Section 5: Again, poor writing, since Dec 27 is a clear day, Jan 2 is a dust event and Jan 4 is a haze event, yet you identify the whole two-week interval as a haze event.

Response: Following the reviewer's comment, the revised manuscript now modifies this sentence. We redefine Dec 27 is a clean day, Jan 2 is a light pollution, Jan 4 is a heavy pollution. (Line 503)

'The event that occurred in Beijing from 27 December 2016 to 9 January 2017 was not only affected by local emissions, but also by regional transport.'

Line 468-475, Section 5: The way this is written it implies some statistics of many days of data in each category of clear, dusty and hazy. In actuality this is only one day of each type and therefore these numbers of very limited value.

Response: Following the reviewer's comment, the revised manuscript now has modified the sentences. We have shown a clear date in the description of the statistics. (Line 508-518)

'It was found that the AOD shows high consistency for the SKYNET skyradiometer and AERONET sunphotometer on the clean day (27 December 2016), light-pollution condition (2 January 2017) and heavy-pollution condition (4 January 2017), and the RMSE are about 0.005, 0.006 and 0.018 respectively. The RMSE of SSA within 10 minutes between SKYNET and AERONET are 0.022, 0.046 and 0.020 on the clean day (27 December 2016), light-pollution condition (2 January 2017) and heavy-pollution condition (4 January 2017), respectively. The biases of SSA are lower when AOD is high. The RMSE of Ångström exponent within 1 minute between SKYNET and AERONET are 0.229, 0.289 and 0.060 for the above three weather conditions respectively, the large biases are due to the low values of AOD (<0.2). The SKTNET and AERONET volume size distributions on the clean day (27 December 2016) and heavy-pollution condition (4 January 2017) present a similar bi-modal pattern, but there are some differences of volume size distribution between SKYNET and AERONET on light-pollution condition (2 January 2017), which is due to lacking AERONET data in clean condition (AOD<0.1) on that day.'

Line 478-479, Section 5: These sentences should be removed since they are vague and it was not clearly shown in the paper why the SKYNET retrievals will have better performance for dust events than for haze events.

Response: Following the reviewer's comment, the revised manuscript now remove this sentence.