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Atmospheric Measurement Techniques Discussions

Interactive comment on "Estimation of aerosol complex refractive indices for both fine and coarse modes simultaneously based on AERONET remote sensing products" *by* Ying Zhang et al.

Ying Zhang et al.

zhangying02@radi.ac.cn

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Dear reviewer:

Thank you very much for your careful review and constructive suggestions with regard to this manuscript. We appreciate for Reviewer's work earnestly, and hope that the corrections will meet with approval. Please find below our detailed responses to reviewer's question and comments.

Referee #3 The paper presents a method to estimate refractive indices for both fine and coarse mode particles. The retrieval from AERONET assumes size-independent

refractive index. The paper assumes that the imaginary part of refractive index has no spectral variation except at 440 nm, while real part of of refractive index has no no spectral variation from 440 - 1020 nm. The size parameters are then derived by fitting lognormal distributions to the inverted size-bin data from AERONET. Mie calculation is conducted to find the sets of both fine and coarse aerosols refractive indices that give the best agreement with AOD and absorbing AOD from AERONET. Overall, the math in this paper is sound. The results presented for Beijing are interesting. The paper needs more justification of its assumptions and more validation.

1) The assumption that the imaginary part of refractive index has no spectral variation except at 440 nm, while real part of of refractive index has no no spectral variation from 440 - 1020 nm. Is this assumption consistent with the assumption in AERONET's inversion algorithm?

Response: Firstly, this assumption is only set to output (CRI of separated fine & coarse modes) of this work, instead of inputs (i.e. the AERONET's inversion products still keep their spectral variation). The objective of this work (separating CRI of fine & coarse modes) focuses on improving the inference of aerosol component information. Figure 1 shows the real parts (n) of the majority of aerosol components are quite constant from UV to near infrared spectral region, and imaginary parts show a significant spectral variation at short wavelengths (e.g. 440nm). This explains our basic consideration on the assumption of the spectral behaviors of output CRIs. In addition, the AERONET algorithm paper stated the similar consideration (Dubovik & King, JGR, 2000):

"Spectral variability is usually not expected for both real and imaginary parts of the aerosol particle refractive index. For example, the widely cited paper by Shettle and Fenn [1979] shows practically wavelength-independent complex refractive indices in the spectral interval of interest (440-1020 nm) for the materials typically composing atmospheric aerosols. Similarly, aerosol models by Tanre et al. [1999] assume single constant values of complex refractive index for the spectral interval considered."

Secondly, we think that this assumption is not in confliction with AERONET's algorithm. The AERONET inversion algorithm assumes identical real and imaginary parts of the refractive indices for both fine and coarse modes coincidently, but allowing independent values at each wavelength (440, 675, 870 and 1020nm). This is mainly to deal with the mixture of mode/components, which can be seen (note: there, "aerosol particles" means mixture of fine & coarse modes) in their paper (Dubovik & King, JGR, 2000):

"However, in the scientific literature there are multiple indications of possible spectral selectivity of the refractive index for aerosol particles [e.g., Ackerman and Toon, 1981; Patterson and McMahon, 1984; Horvath, 1993; Dubovik et al., 1998b, Yumasoe et al., 1998]. Therefore we constrain the spectral variability of the retrieved complex refractive index to some practically reasonable ranges rather than to any particular model of the atmospheric aerosol."

2) In cases/locations when AERONET's inversion shows dominant fraction ($\sim$100%) of fine-mode aerosols, its retrieved index of refraction should be considered as appropriate for fine-mode aerosols. The same holds true when aerosols are dominated by coarse particles. There are AERONET sites close to Gobi desert. It will be valuable to look at several cases where dust particles are transported from Gobi desert to Beijing, and compare the retrieved index of refraction for coarse mode in Beijing with that directly retrieved from AERONET site close to the dust source.

Response: According to the Reviewer's comments, we choose a dust event period from Apr. 17-19 2017 both at Beijing site and Dalanzadgad site close to Gobi desert in Mongolia (Fig. S1a). The dust aerosol in Beijing transported from Dalanzadgad site can be seen clearly in Fig 1b, simulated by HYSPLIT model reached Apr. 20, 2017. The high concentrations of volume particle size distributions in coarse mode (Fig. S2) are similar at Dalanzadgad and Beijing site. It is indicate that the similar properties of dust can be observed at both Beijing and Dalanzadgad sites. Fig. S3(a) and (b) shows a fairly good consistency of the real parts (n) at Dalanzadgad from AERONET and the retrievals for coarse mode in Beijing from our algorithm and close to 1.6, although the

observed time is not an exact match. But the imaginary parts do not agree each other. It can be explained by the variation of transported aerosol properties. In addition, some uncertainties can be involved in analysis and retrieval because the AERONET Lev 1.5 data is used in this part. Particularly, the strong absorption (large k) in Dalanzadgad site on Apr. 17 is inveracious.

To further detect the accuracy of coarse mode, additional three typical dust aerosol model (Dubovik et al., 2002) are employed and combined with the fine-mode WS and BB (Table 1). As the Table S1 shows, The error of real part in coarse mode is lower than 0.1, and the retrieved imaginary part of CRI in coarse mode is more accurate with the error of less than 0.003 except for the biomass burning model.

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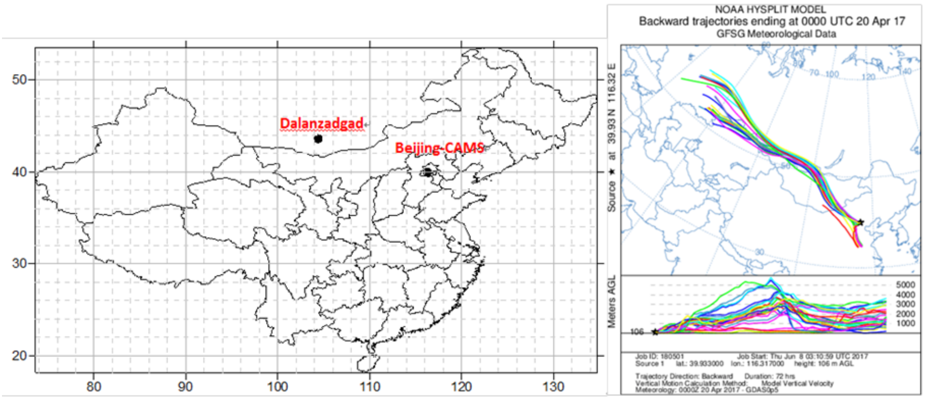

Fig. 1. (a) Map of site locations; (b) backward trajectory on Apr. 17-19, 2017

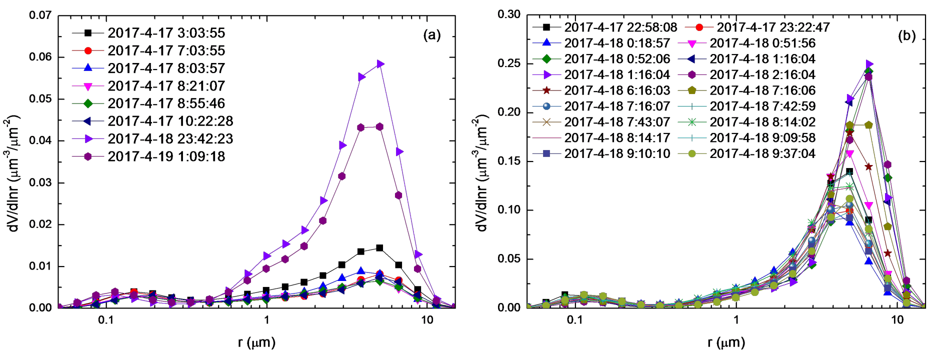

Fig. 2. volume particle size distributions of (a) Dalanzadgad and (b) Beijing site during Apr. 17-19, 2017.

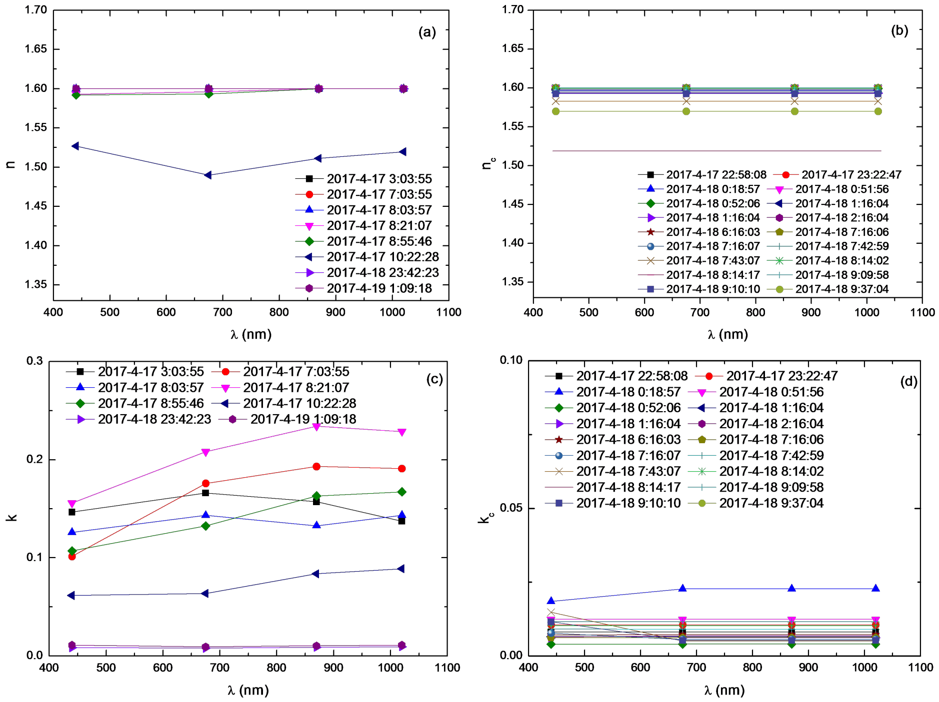

Fig. 3. The comparison of CRI from AERONET at Dalanzadgad site (a, c) and retrieved one in coarse mode at Beijing site (b, d).

Table S1. The retrieved errors of typical dust aerosol models.

Aerosol model	Input CRI in coarse mode			Error in coarse mode		
	n_c	$k_{c,440}$	k_c	n_c	$k_{c,440}$	k_c
WS	1.55	0.0025	0.001	-0.091	0.000	0.003
	1.56	0.0029	0.001	-0.099	0.000	0.003
	1.48	0.0025	0.0006	-0.033	0.000	0.003
BB	1.55	0.0025	0.001	-0.013	0.018	0.022
	1.56	0.0029	0.001	-0.022	0.018	0.021
	1.48	0.0025	0.0006	0.054	0.019	0.022
DU	1.55	0.0025	0.001	-0.008	0.000	0.000
	1.56	0.0029	0.001	-0.009	0.000	0.000
	1.48	0.0025	0.0006	-0.010	0.000	0.000

Fig. 4.