Author's changes in manuscript

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1. Line 6: “receiving” is replaced as “received”

1. Line 7: “the” after “along” is replaced “its”; “of the radar wave” is deleted

2. Line 9: “charge” is replaced as “charges”; “Particle charging is common in a particle system” is revised to “It is common that the particles can be electrified in a particulate system to make particles carry net charges on their surfaces”.

3. Line 11: “emission” is deleted

4. Line 12: “emission frequency of the radar” is changed as “radar frequency”

5. Line 13: “number density of particles” is changed as “The total particle number per unit volume (particle number density)”.

6. Line 15: “overestimation” is changed as “overestimation rate”; “with” is replaced as “as”; insert “increases” after “density”; “for” is replaced as “by”

7. Line 18: “;” after “weather” is replaced as “,”

8. Line 20: “electromagnetic (EM) waves” is replaced as “electromagnetic waves (EMWs)”

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9. Line 1: “Systems that employ microwave radar and lidar” is replaced as “radar and lidar systems (employed EMWs technology)”; “of” is replaced as “such as”

10. Line 3: “;” after “weather” is replaced as “,”; “transported” is replaced as “blown”

11. Line 7: “that can be placed” is replaced as “carried by”

12. Line 8: "charge" is replaced as "charges"; "placed on" is replaced as "carried by"

13. Line 9: "charge" is replaced as "charges"

14. Line 10: "EM waves" is replaced as "EMWs"

15. Line 13: "EM waves" is replaced as "EMWs"; "particle size parameter" is replaced as "size parameter *x*"; add "*x*=" before "2"

16. Line 14: "EM" is replaced as "EMW"

17. Lines 14-17: "The main functions … the signal backscattering by particles" is replaced as "Usually, some particle properties, such as the particle size distribution and particle number density can be inversely deduced based on the received power for a known transmitting power or the ratio of received power to transmitting power (RPR) which depends on the extinction signal, especially the signal backscattered by particles."

18. Line 17: delete "strength"

19. Line 18: "charge" is replaced as "charges"

20. Line 20: "We therefore" is replaced as "Therefore, we"

Page 3 (**Section 2** is totally re-written, including changing the title, rearranging the formula number, and revising the corresponding content.)

21. Line 5: add "a radar/liar detecting"

22. Lines 6-20 is replaced as "A radar detection system transmits an EMW that propagates through an atmosphere particle system, and the return signal of the EMW is received usually, but not always, by the same radar system (Mona et al., 2012;Ahmed, 2008), a schematic of which is shown in Fig. 1(a). Denoting the received power as $P_r(q)$, the

transmitting power as P_t, the detection range as R, and the beam widths as $\Delta\phi$ and $\Delta\theta$, the received power of a designed radar system can be calculated by using the conventional radar equation (Fukao et al., 2014),

$$P_r(q) = P_t \frac{G^2\lambda^2\Delta\phi\Delta\theta\tau c}{2^{10}\ln 2\pi^2 R^2}\beta(q)\times 10^{-2\int_0^R \sigma_{ext}(q)dl/10}, \quad (1)$$

where G is the antenna gain, and λ and τ are respectively the wavelength and duration of the emitted EMW. $\beta(q)$ and $\sigma_{ext}(q)$ are the backscattering cross-section and the extinction cross-section of atmospheric particles per unit volume in contact with the EMW along its propagating path when considering the particles electrified, shown as in Fig.1(b). While the backscattering cross-section per unit volume and the extinction cross-section per unit volume of the neutral atmospheric particles are defined as $\beta(0)$ and $\sigma_{ext}(0)$. $\beta(q)$ and $\sigma_{ext}(q)$ can be calculated by (2) based on Mie theory

$$\begin{aligned} \beta(q) &= \int_{r_{\min}}^{r_{\max}} \pi r^2 Q_{bac}(q,r)n(r)dr \\ \sigma_{ext}(q) &= \int_{r_{\min}}^{r_{\max}} \pi r^2 Q_{ext}(q,r)n(r)dr \end{aligned}, \quad (2)$$

where $r_{\min}$ and $r_{\max}$ are the minimum and maximum particle radii, respectively. $n(r)$ is the number density distribution of the atmospheric particles._$Q_{bac}(q, r)$ and $Q_{ext}(q, r)$, the backscattering coefficient and the extinction coefficient can be calculated by the scattering filed of a single particle carrying charges on its surface illuminated by EMWs shown as in Fig. 1(b), to refer to the detailed derivation by Klačka and Kocifai (Klačka and Kocifai, 2007),

$$\begin{aligned} Q_{ext}(q,r) &= \frac{2}{x^2}\sum_{n=1}^{\infty}(2n+1)\operatorname{Re}\left(a_n(q)+b_n(q)\right) \\ Q_{bac}(q,r) &= \frac{1}{x^2}\left|\sum_{n=1}^{\infty}(2n+1)(-1)^n\left(a_n(a)-b_n(q)\right)\right|^2 \end{aligned}, \quad (3)$$

where Re(·) denotes the real part of a complex number. $a_n(q)$ and $b_n(q)$ are the Mie scattering coefficients of the scattering

field of EMWs by a surface-"

Page 4 (whole of P4 text and formulas as revised because of rearrangement of **Section 2**)

23. Lines 1-15 is replaced as "charged particle without considering the magnetism of the particle material, and are analytically expressed as (Klačka and Kocifai, 2007;Zhou and Xie, 2011;Bohren and Hunt, 2011)

$$a_n(q)=\frac{\psi_n(x)\psi_n'(mx)-m\psi_n'(x)\psi_n(mx)-i\omega k^{-1}\mu_0\sigma_s\psi_n'(x)\psi_n'(mx)}{\xi_n(x)\psi_n'(mx)-m\xi_n'(x)\psi_n(mx)-i\omega k^{-1}\mu_0\sigma_s\xi_n'(x)\psi_n'(mx)}$$
$$b_n(q)=\frac{\psi_n'(x)\psi_n(mx)-m\psi_n(x)\psi_n'(mx)+i\omega k^{-1}\mu_0\sigma_s\psi_n(x)\psi_n(mx)}{\xi_n'(x)\psi_n(mx)-m\xi_n(x)\psi_n'(mx)+i\omega k^{-1}\mu_0\sigma_s\xi_n(x)\psi_n(mx)}, \quad (4)$$

where $\psi_n(x)=xj_n(x)$ and $\xi_n(x)=xh_n^1(x)$, in which $j_n(x)$ and $h_n^1(x)$ are the first-order Bessel function and spherical Hankel function, respectively. m is the relative refractive index. $i=\sqrt{-1}$. $\omega = 2\pi c/\lambda$ is the circular frequency and $k = 2\pi\lambda/c$ is the wave number of the EMW. $\mu_0 = 1.256\times10^{-6}$ is the permeability of a vacuum. σ_s is the surface conductivity analogous to the (bulk) conductivity and it may be complex and depend on the wave frequency. Bohren and Hunt (Bohren and Hunt, 2011) and Klačka et al. (Klačka and Kocifaj, 2007;Klačka. and Kocifaj, 2010) presented a detailed study on σ_s, usually expressed as $\sigma_s=\frac{i\sigma q_m}{\omega+\gamma_s}$, where σ is the surface charge density, and $q_m = 1.7587\times10^{12}$ C/kg is the charge-mass ratio of an electron, and γ_s is equal to $k_BT/\hbar$, with T being the particle temperature (T=273K) and $k_B = 1.38\times10^{-23}$J/K and $\hbar = 1.0546\times10^{-34}$Js being Boltzmann's constant and Planck's constant, respectively (Klačka and Kocifaj, 2007). Without considering the charges carried by the particles, the backscattering coefficient and the extinction coefficient $Q_{bac}(0)$ and $Q_{ext}(0)$ can be calculated by the classical Mie coefficients $a_n(0)$ and $b_n(0)$ (Bohren and Huffman, 1983),

$$a_n(0)=\frac{\psi_n(x)\psi_n'(mx)-m\psi_n'(x)\psi_n(mx)}{\xi_n(x)\psi_n'(mx)-m\xi_n'(x)\psi_n(mx)}$$
$$b_n(0)=\frac{\psi_n'(x)\psi_n(mx)-m\psi_n(x)\psi_n'(mx)}{\xi_n'(x)\psi_n(mx)-m\xi_n(x)\psi_n'(mx)}, \quad (5)$$

For lidar system, the received power is calculated by (Collis, 1970)

$$P_r(q)=P_t\frac{\tau cA}{R^2}\beta(q)\times\exp\left(-2\int_0^R\sigma_{ext}(q)dl\right), \quad (6)$$

where A is the area of the receiver aperture. We defined the ratio of the received power $P_r(q)$ to the transmitting power P_t as $RPR_r(q)$ for a radar system and $RPR_l(q)$ for a lidar system, respectively, which are mathematically expressed as following, according to Eqns. (1) and (2),

$$RPR_r(q)=\frac{G^2\lambda^2\Delta\phi\Delta\theta\tau c}{2^{10}\ln 2\pi^2R^2}\beta(q)\times10^{-2\int_0^R\sigma_{ext}(q)dl/10}$$
$$RPR_l(q)=\frac{\tau cA}{R^2}\beta(q)\times\exp\left(-2\int_0^R\sigma_{ext}(q)dl\right), \quad (7)$$

Actually, many atmospheric particles are commonly electrified, such as sand particles, dust particles, rain drops, haze particles and foggy drops. When these particles are detected by a radar system or a lidar system, and received power by the radar/lidar system includes the contribution of the charges carried by the particles and the particles themselves. The researches on the attenuation of the EMWs by the charged particles system indicate that the charges carried by particles have a significant contribution to the extinction coefficient(Klačka and Kocifaj, 2007) and the backscattering coefficient(Kocifaj et al., 2015). Therefore, from (7), it can be found that the received power of a radar/lidar system also includes the contribution of the charges carried by the particles, and in this paper we use the following ratio to investigate the effect of the charges carried by the atmospheric particles on the received power of a radar/lidar system,

$$\begin{aligned} \frac{RPR_r(q)}{RPR_r(0)} &= \frac{\beta(q)\times 10^{-2\int_0^R \sigma_{ext}(q)dl}}{\beta(0)\times 10^{-2\int_0^R \sigma_{ext}(0)dl}} \\ \frac{RPR_l(q)}{RPR_l(0)} &= \frac{\beta(q)\times \exp\left(-2\int_0^R \sigma_{ext}(q)dl\right)}{\beta(0)\times \exp\left(-2\int_0^R \sigma_{ext}(0)dl\right)} \end{aligned}, \tag{8}$$

In which $RPR_r(0)$ and $RPR_l(0)$ are the ratio of the received power to the transmitting power for a radar system and a lidar system without considering the contribution of the charges carried by the particles. ”

24. Add a paragraph in **Section 3** (first paragraph in **Section 3**) to show the results of RPR for different size-distributed particle system, as,

From (8), it can be found that $RPR_{r/l}(q)/RPR_{r/l}(0)$ is related to the ratio of the backscattering cross-section of charged atmospheric particles to the one of neutral atmospheric particles per unit volume, which is detailed studied by Kocifaj et al, and they found that an increasing amount of charge on cloud droplets strengthens the backscattering of a radar wave. In addition, $RPR_{r/l}(q)/RPR_{r/l}(0)$ is also related to the detection range R and the particle number density N and the number density distribution $n(r)$ which is directly proportional to the particle size distribution. Here, we firstly investigate the effect of charges carried by the particles on the $RPR_{r/l}(q)/RPR_{r/l}(0)$ assuming that the particles have a single size, shown as in Fig.2. As the study presented by Chiou and Kiang(Chiou and Kiang, 2017) indicates that the earth curvature and height profile of sand and dust storm have an effect on the radar backscattering, which depends on the detection range. They proposed a parabolic wave equation (PWE)-based radar equation to improve the conventional radar equation, and they found when the range is 3km, the received powers predicted with the PWE-based radar equation and the conventional radar equation are close each other(Chiou and Kiang, 2017). Therefore, we choose the detection range as R=3km hereafter. And the maximum particle number density along the detection range is chosen $10^7/m^3$ as the one used by Chiou and Kiang, and we assumed that N is not dependent on the detection range here. Fig.2 (a) shows the change of $RPR_{r/l}(q)/RPR_{r/l}(0)$ of a radar system in the particle radius under different surface charge densities, with σ=0.5μC/m^2, σ=1.0μC/m^2 and σ=100μC/m^2, from which it can be found that the charges carried on the particle surface make the $RPR_r(q)$ larger than the $RPR_r(0)$ without considering the charges carried on the particles surface, especially for smaller particle. The more the charges are, the larger the $RPR_r(q)/RPR_r(0)$ is, for the wave frequency f=4GHz and the relative refractive index m=2.1365-0.059i. We also plot the ratio of the backscattering coefficient of single-size charged particles to the one of the corresponding neutral particles into the insert figure in Fig.2 (a), which is same as the one reported by Kocifaj et al, and it is almost equal to the $RPR_{r/l}(q)/RPR_{r/l}(0)$, that means $\mathbf{10^{-2\int_0^R[\sigma_{ext}(q)-\sigma_{ext}(q0)]dl/10}}$ in (8) is almost equal to 1. The $RPR_{r/l}(q)/RPR_{r/l}(0)$ is plotted in Fig.2(b), from which it can be found that charges carried on the particle almost have no effect on the ratio of the received power to the transmitting power of a lidar (f=5.6×10^{14}GHz).

25. Line 21: "Fig. 2" is replaced as "Fig.3"; add "of the particle number density" between "expression" and "is"

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26. Line 1: formula (6) is replaced as

$$n(r)=\frac{N}{\sqrt{2\pi}\ln\sigma_r}\exp\left[-\frac{\ln r-\ln\bar{r}}{2(\ln\sigma_r)^2}\right]=Np(r)$$

27. Line 2: delete "N is the … volume and"; move "respectively" backward to "radius"

28. Line 3: add ", and $p(r)$ is the size distribution density function of particles." before "Particle"

29. Lines 3-4: "and the frequencies …different;" is replaced as "with different EMW frequencies,"

30. Line 7: add "of radar/lidar systems" after "RPR"; "ratio … charges" is replaced as "$RPR_{r/l}(q)/RPR_{r/l}(0)$"

31. Line 8: "Fig.3" is replaced as "Fig.4"

32. Line 9: "3" is replaced as "4"

33. Line 10: "RPR(c)" is replaced as "$RPR(q)$"; "greater" is replaced as "larger"

34. Lines 11-13: "The increment of …in Fig. 3(a)-3(d)" is replaced as "The $RPR_{r/l}(q)/RPR_{r/l}(0)$ is not linearly dependent on the particle radius as shown in Figs. 4(a)-4(d)."

35. Line 13: "RPR" is replaced as "$RPR_{r/l}(q)$"

36. Line 17: "RPR(c)/RPR(0)" is replaced as "$RPR_{r/l}(q)/RPR_{r/l}(0)$"

37. Line 18: "4" is replaced as "5"

38. Line 19: "emission frequency of the radar" is changed as "radar frequency"; "RPR(c)/RPR(0)" is replaced as "$RPR_{r/l}(q)/RPR_{r/l}(0)$"

39. Line 20: delete "emission"; "4" is replaced as "5"; "RPR(c)/RPR(0)" is replaced as "$RPR_{r/l}(q)/RPR_{r/l}(0)$"; "for" is replaced as "by"

40. Line 21: delete "emission"

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41. Line 1: "emission" is replaced as "EMW"; delete " Dou and Xie, 2017"

42. Line 2: "RPR" is replaced as "$RPR_{r/l}(q)$"

43. Line 3: "3 and 4" is replaced as "4 and 5"; "receiving" is replaced as "received"; delete " if the radar is well designed"

44. Line 4: add "distribution" between "density" and "*n*(*r*)"; delete "per unit"

45. Line 5: "receiving" is replaced as "received"

46. Lines 5-10: "However, the … in the reverse calculation" is replaced as "The received power by the radar/lidar system includes the contribution of the charges carried by the particles and the particles themselves. However, the contribution of the charges to the received power is not considered in the current radar design, which is attributed to the power of scattering by the particles, and it could result in the mis-estimation of particle properties, such as *N*. We denote the particle number density determined by radar received power considering charges carried by the particles as *N*(*q*), and that without considering charges as *N*(0). Because $10^{-2\int_0^R[\sigma_{ext}(q)-\sigma_{ext}(q0)]dl/10} \approx 1$, the particle number density can be by the backscattering cross-section and RPR, as

$$N(q) = \frac{RPR_r(q)}{\int_{r_{\min}}^{r_{\max}} \pi r^2 Q_{bac}(q,r)p(r)dr}$$
$$N(0) = \frac{RPR_r(0)}{\int_{r_{\min}}^{r_{\max}} \pi r^2 Q_{bac}(0,r)p(r)dr}, \quad (10)$$

Thus, let $RPR_r(q) = RPR_r(0)$, the ratio *N*(*q*)/*N*(0) can be derived as,

$$\frac{N(q)}{N(0)} = \frac{\int_{r_{\min}}^{r_{\max}} \pi r^2 Q_{bac}(0,r)p(r)dr}{\int_{r_{\min}}^{r_{\max}} \pi r^2 Q_{bac}(q,r)p(r)dr}, \quad (11)$$

"

47. Line 10: "overestimation" is replaced as "overestimation rate"

48. Line 11: "*N*(*c*)" is replaced as "*N*(*q*)"; "overestimation" is replaced as "overestimation rate"

49. Line 12: "N(c)/N(0) … Fig. 5" is replaced as "*N*(*q*)/*N*(0) detected by a different radar is different even that the particles carry equal charges as shown in Fig. 6"

50. Line 13: "overestimation" is replaced as "overestimation rate"; "emission frequency of the radar" is replaced as "radar frequency"

51. Line 14: "the table" is replaced as "Table 1"; "overestimation" is replaced as "overestimation rate"

52. Lines 15-16: “We therefore” is replaced as “Therefore, we”

53. Line 16: add “on the detection data” in the end of this sentence

54. Line 17: add “of radar/lidar systems after “RPR”

55. Line 20: add “of radar/lidar systems after “RPR”

56. Line 21: “greater” is replaced as “larger”; “receiving” is replaced as “received”

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57. Line 2: delete “emission”

58. Line 4: replace “of” as “with”

59. Line 5: replace “receiving” as “received”; “overestimation” is replaced as “overestimation rate”

60. Lines 5-6: “frequency of the radar” is replaced as “radar frequency”

61. Line 6: replace “Calculation” as “Calculated”, “overestimation” as “overestimation rate”

62. Line 7: insert “based on the received power of” between “determined” and “a lidar”; delete “by”

63. Lines 8-10 is re-written, and move to last paragraph of Section 3, as “According to the RPR when considering charges carried by particles, the estimation of the particle number density for sand/dust weather based on the received power of radar systems with different radar frequency was discussed, and it was found that the particle number density can be overestimated when not considering the contribution of the charges carried by the particles to the received power. The overestimation rate depends on the surface charge density and radar frequency. Calculated results of the overestimation rate of the sand particle number density indicate that the effect of charges carried by particles can be ignored when the particle number is determined based on the received power of a lidar.

64. Line 12: replace “from” as “of”

65. Line 13: replace “Nos” as “No”

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66. delete lines 9-10

67. Line 17: “Hu Q.” is replaced as “H. Qin”

Captions of figures and table are revised as,

68. Fig. 1 (a) Schematic of the radar system detecting of an atmospheric particle system; (b) surface-charged atmospheric particle.

69. Figure is added in revised manuscript.

Fig. 2 (a) $RPR_r(q)/RPR_r(0)$ and (b) $RPR_l(q)/RPR_l(0)$ versus particle radius in the case of the particles carrying three surface charge density, σ=-0.5μC/m^2, σ=-1.0μC/m^2 andσ=-100μC/m^2, radar frequency and the relative refractive index in (a) f=4.0GHz and m=2.1365-0.059i, and in (b) f=5.6×10^{5}GHz and m=1.53-0.008i. Insert figure is the ratio of the backscattering coefficient of the charged particle to the one of the neutral particle versus particle radius.

70. Fig. 3 Size distributions of four particle types: (a) haze particles, (b) cloud particles, (c) dust/sand particles and (d) rainfall particles.

71. Fig. 4 $RPR_{r/l}(q)$/ $RPR_{r/l}(0)$ versus particle radius with particles carrying different surface charge density detected by (a) lidar system, (b) W-band radar system, (c) X-band radar system and (d) S-band radar system.

72. Fig. 5 $RPR(q)/RPR(0)$ of a radar/lidar system detecting a sand particle system.

73. Fig. 6 $N(q)/N(0)$ of the sand particle number density detected by different radar/lidar system versus the

surface charge density carried by particle.

74. Table 1. Overestimation rate of the sand particle number density detected by different radar systems when the four surface charge densities carried by particles