Response to reviewers' comments

Dear Reviewer:

Thank you for your comments on our manuscript. Your comments are valuable for improving our manuscript. We have tried our best to revise the manuscript according to your comments and suggestions, and we have responded to the your comments and suggestions point by point. The following are our answers to editor's and the reviewer's comments.

Thank you very much!

Yours Sincerely,

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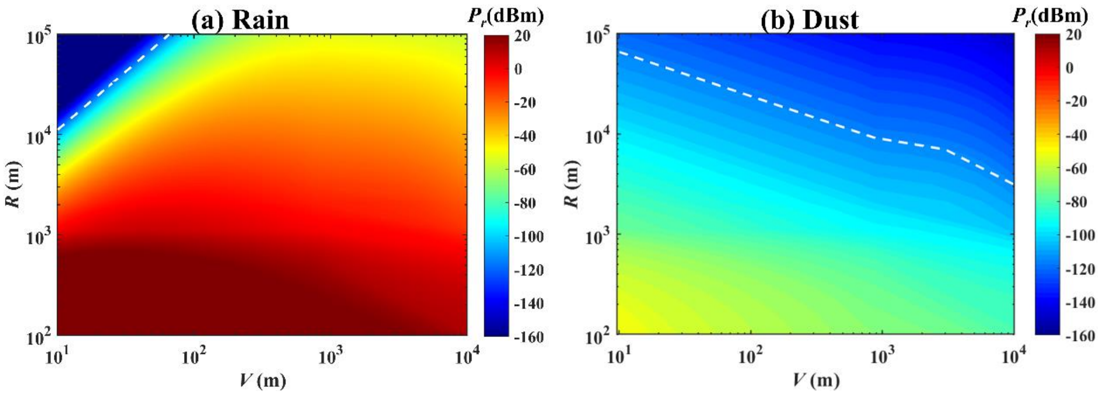
Comments from the reviewer:

Comment 1:

The paper presents results of simulated detection capability for dust storms by using various radar types and lidar. The simulation considers various dust concentrations mostly expressed as visibility by human eye, and includes effects of relative humidity and electric charge for fixed particle concentrations. Based on the simulation results, the authors propose to use radar of different wavelength and lidar to detect dust storms. The paper does not attempt to calculate the influence of polarization diversity of radar and lidar to distinguish dust storm returns from other returns; this is reasonably not scope of the paper. All calculations are based on spherical particles.

Authors' reply: Thanks for your comments. Yes, in this paper we only propose to use radar of different wavelength and lidar to detect the intensity of dust storms, and we do not calculate the influence of polarization of radar and lidar to distinguish dust storm returns from other returns, which is a good suggestion, and we will do it in future. Here, we calculated the detection range of C-band radar by raindrops as following Figure. From the Figure, it can be found easily that detection range is extended compared to the sandy dusty weather, and it can be found that the effective detection range is beyond 100 km except visibility lower than 65 m for raindrops.



Although the sand particles are not always perfect spheres, a study on the shapes of dust particles conducted by Ilan Koren et al. showed that most of dust aerosol particles were spherical (Koren et al., 2001). Therefore, we assume that the sand and dust particles are spherical particles in this paper.

Comment 2:

The English language is fair to poor which makes it sometimes difficult to follow the authors' argument. The authors should try to seek for support from a native English-speaking person or someone being firm with English language.

Authors' reply: We are sorry for the poor descriptions to confuse you. We've checked the manuscript thoroughly and rewritten most parts of the text.

Specific comments:

Comment 3:

Table 1 (and general): Why is C-band radar not considered? It is one of the most common types of meteorological services.

Authors' reply: Thanks for your suggestion, and we include C-band radar in Table 1 and calculate the echo power of C-band radar in Figures.2, 4-6. Results show that it is good choice to detect dusty weather by combining C-band radar and lidar.

Comment 4:

Table 1: Lidar characteristics given indicate a device transmitting visible light with a pulse power of 4 kW. Such lidar is far from being eye-safe and thus not very likely to be used as a scanning device.

Authors' reply: We are so sorry that we make a mistake, and the transmit power of lidar (560 THz) should be 110 mJ, and we've corrected it in the revised manuscript.

Comment 5:

Fig.2 (and others): The analysis is limited to a range of 10 km. Most ground-based precipitation radar can detect dust storms at much larger distances; observations beyond 100 km have been reported. The authors should extend the analyses, at least for figures 2 and 3, to at least 50 km (better 100 km) range. Detection ranges below 100 meters need not to be considered.

Authors' reply: It is a good suggestion. We calculated echo power of radars and lidar with the maximum detection range 100 km given the visibility as following Figures 1-2 (Figures 5-6 in revised paper). Microwave radars show their excellent ability of detection dusty weather with low visibility, such that C-band radar can get the effective echo power with the detection range of 60~70 km shown as Figure 1(d) and Figure 2(d) when V=10 m. According to your suggestion, the echo power of radars and lidar with detection ranges below 100 m was not considered in the revised manuscript.

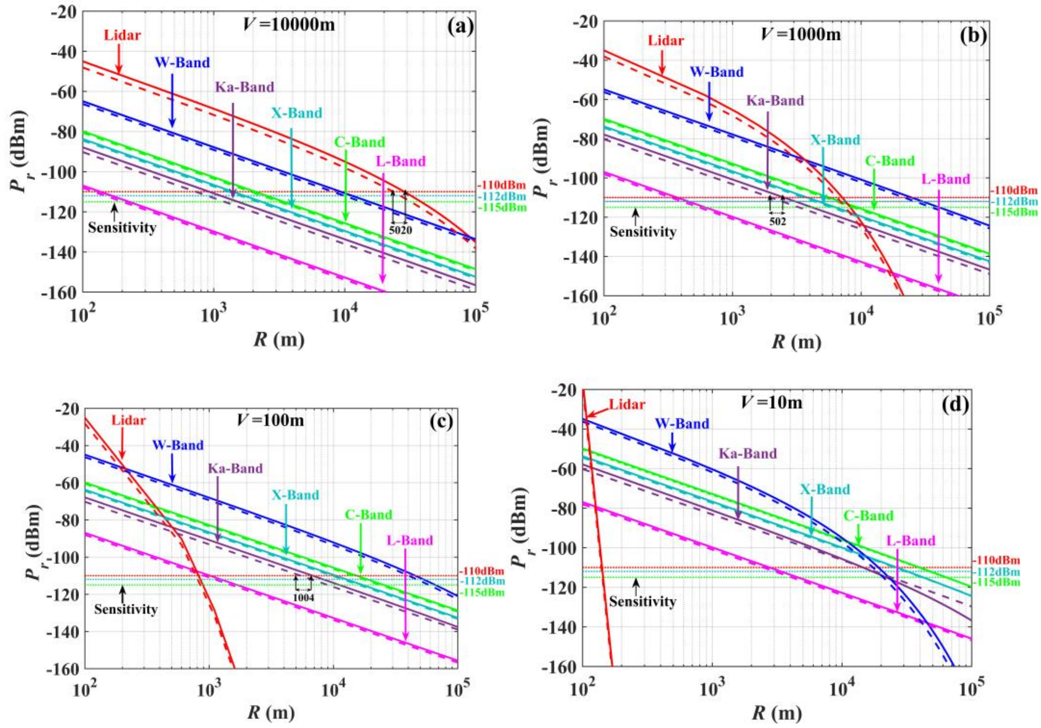


Figure 1. Echo power varying with the detection range given the visibility (a) 10000 m (floating dust), (b) 1000 m

(blowing sand), (c) 100 m (strong dust storms) and (d) 10 m (severe dust storms), and the solid lines and the dash lines with the consideration of *RH*=80% and *RH*=0%. Particles are neutral. The sensitivity of the six bands of radars/Lidar are -112 dBm, -115 dBm, -112 dBm, -110 dBm, -110 dBm, and -110 dBm, respectively.

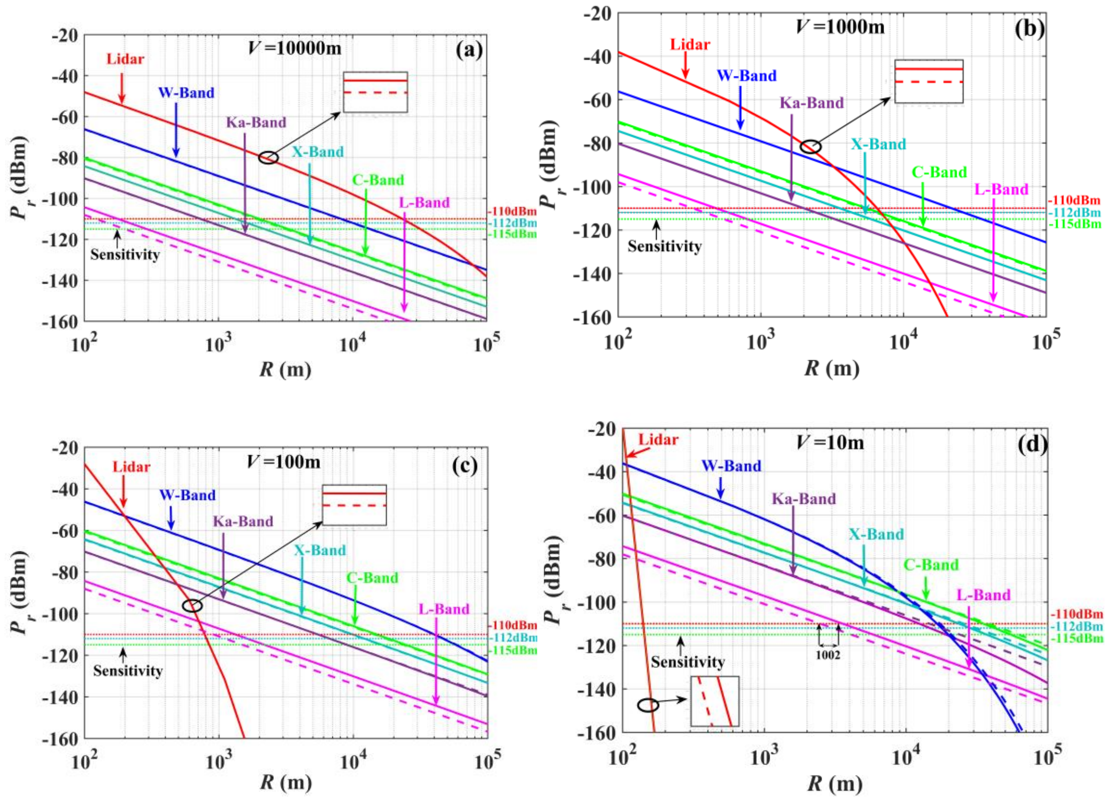


Figure 2. Echo power varying with the detection range given the visibility (a) 10000 m (floating dust), (b) 1000 m (blowing sand), (c) 100 m (strong dust storms) and (d) 10 m (severe dust storms), and the solid lines and the dash lines with the consideration of η=-2000 μCm^{-2} and η=0 μCm^{-2}, without consideration of effect of *RH*. The sensitivity of the six bands of radars/Lidar are -112 dBm, -115 dBm, -112 dBm, -110 dBm, -110 dBm, and -110 dBm, respectively.

Comment 6:

Section 2.3, manuscript lines 172ff: "centimeter-band radar has not yet been used to detect sandy dust weather" and "for sandstorms that occur in desert areas, it is impossible to detect them from such a long distance." Both is not correct. Centimeter wavelength radar is used since decades for dust storm detection, see e.g. Hannesen and Weipert, 2003, and Saeed at al 2014.

Authors' reply: We are so sorry that our statements are too arbitrary. We have rewritten these sentences. It is indeed that centimeter wavelength radar is used since decades for dust storm detection as described by Hannesen and Weipert as "Weather Radars are able to detect dust storms, if the number concentration and size of dust particles is large enough(Hannesen and Weipert, 2003)."

Comment 7:

Fig. 2 b and c: According to the authors' calculation, the detection range of centimeter-wavelength radar is limited to about 10 km for visibilities of several hundred meters.

But in Saeed at al 2014 (e.g., figs 6 and 7), detection range of the Kuwait C-band radar is about 100 km for similar visibilities. The authors need to revise their calculation and should comment on such huge discrepancy.

Authors' reply: Thanks a lot! We've checked our calculation, and it is correct. We accepted your suggestion, and we calculated the echo power of C-band radar to see Figure 2 in the revised manuscript. The maximum detection range calculated is about 66 km, which is still much lower than the experimental results, about 100km. There are two sides to make such gap between the calculated results and the experimental ones. The one is due to dust particles with different particle sizes in our manuscript and in Saeed et al.'s work, and the other is due to the fact that we assume that the visibility of dusty weather is uniformly distributed along the transmission route, while only partial areas within the detected range appeared dusty weather in Saeed et al(Saeed et al., 2014). Therefore, the attenuation of the radar waves on the transmission path is more severe in our calculations, resulting in a smaller effective detection range than in Saeed et al. We added the comment on the discrepancy between the calculated results and experimental results in the revised manuscript to see lines 56 – 61, page 2. Fortunately, all the echo powers of different radars and lidar are calculated under such same assumption, and it cannot affect to investigate the detection ability of different radars and lidar. Therefore, it cannot affect the scheme. It should further confirm the visibility and the real conditions should be considered in real detection.

Comment 8:

Fig. 2 f and discussion in the text: The authors should compare their derived detection ranges with those according to ISO 28902-2:2017

Authors' reply: Thanks for your suggestions. We are sorry that we did not find ISO 28902-2:2017. But fortunately, we find experimental results of detection range of Ka-band radar in dusty weather observed by Ming et al., and we compare it with our calculated results shown as in figure4 (Figure 2(d) in revised manuscript).

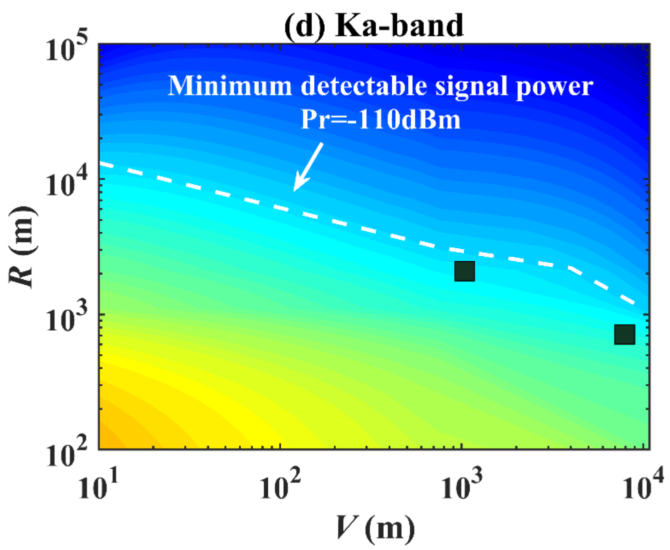


Figure 4. Echo power contour maps of Ka-band radar varying with the visibility *V* of the dusty weather and the detection range *R*, and white dash lines are the minimum detectable signal power (sensitivity) of the given radar or lidar. Squares in (d) are experimental results in dust storms (V<1km) at a height of 2000 m and blowing sand (1km<V<10km) at a height of 600 m.

Comment 9:
Fig. 3: This figure should be given also for a visibility of 100 meters (not only for 10 and 1,000 meters)
Authors' reply: Thanks for your suggestions, and we have calculated the results under visibility of 10m to see Figures 5-6 in the revised manuscript.

Comment 10:
Section 4 (manuscript lines 228-308): The authors describe the influence of electric particle charge and relative humidity in many sentences, with the data given being of limited value. For the reader, e.g., "considering the influence of relative humidity, when detecting severe sandstorms, the effective detection range is reduced by 502 m and increased by 201 m, respectively" means that he has to figure out to which original data such reduction refers to. A reduction by 502 m is significant if it means e.g. from 2,000 down to 1,498 meters, but it is marginal if it means e.g. from 20,000 down to 19,498 meters. Instead of many such sentences, the authors should present a few tables with all these data and should summarize the tables in the text.
Authors' reply: We are so sorry that the descriptions make you confused. And we have rewritten this part to see Figures 1-2 above (also to see Figures 5-6 in revised manuscript). It can be found that given V, the echo powers of all radars decrease as the detection range increasing, and the RH and charges cannot change this trend of P_r~R, but RH and charges can enhance the effective detection range such that the effective detection range of lidar with V=10000m is enhanced about 5km to see Figure 5(a) with RH increased to 80%, which is 1/5 of the effective detection range (RH=0%), about 25 km. From Figure 6(d), it can be found that the excess charge of η=-2000 μCm^{-2} carried by the particles results in the effective detection range enhanced by 1002 m for the L-band radar, which is 38.3% of the effective detection range by the dry neutral sand particles. However, the same excess charge results in the effective detection range enhanced by only 1.3% for C-band radar.

References

Hannesen, R. and Weipert, A.: Detection of dust storms with a C-band Doppler radar, 2003.

Koren, I., Ganor, E., and Joseph, J. H.: On the relation between size and shape of desert dust aerosol, Journal of Geophysical Research: Atmospheres, 106, 18047-18054, 2001.

Saeed, T., Al-Dashti, H., and Spyrou, C.: Aerosol's optical and physical characteristics and direct radiative forcing during a shamal dust storm, a case study, Atmospheric Chemistry and Physics, 14, 3751-3769, 2014.