Response to reviewer' comments

Dear Editors and Reviewers:

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 your comments and suggestions point by point as following.

Thank you very much!

Yours Sincerely,

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Comments from the reviewer:

It is challenging to follow the manuscript due to poor use of English language. I would suggest the authors to have their manuscript checked by a native English speaker or somebody with fine English proficiency prior to the initial submission. The manuscript in its current form strains the voluntary review process.

***Authors' reply*:** Thank you very much for your review and suggestions. We are so sorry for the poor descriptions to confuse you. We've checked the manuscript thoroughly and rewritten the text.

Specific comments

1. Please give more details on the chosen parameters for the particle size distributions in section 2.1. How much does the maximum detection range depend on the number of very small particles in relation to fewer larger particles? How are \bar{r} and \sigma_r related to V?

***Authors' reply*:** Generally, particles with a diameter greater than 80 microns are difficult to be directly blown to higher than 2m by wind, while smaller dust particles can rise to a height of several kilometers by strong wind, and can be transported to a long distance. Therefore, the sandy dust particles less than 80 microns are chosen and the particle size distribution obeys lognormal distribution as follows

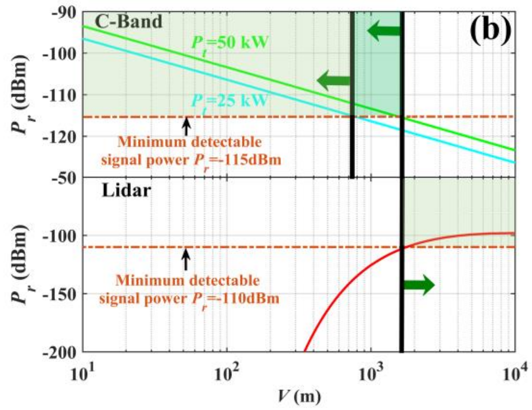
$$p(r) = \frac{1}{\sqrt{2\pi}\ln\sigma_r}\exp\left[-\frac{\ln r - \ln\bar{r}}{2(\ln\sigma_r)^2}\right]$$

Where $\bar{r}$ and σ_r are the average and standard deviation of the particle radius, respectively. The average particle radius $\bar{r}$ is also a function of height, which can be represented as $\bar{r} = \bar{r}_0 h^{-\gamma_m}$, where $\bar{r}_0$ is the average particle radius at 1 m above ground, and $\gamma_m = 0.15$, $\bar{r}_0 = 18.4$ μm and σ_r=2. We have added the information of particle size has been added in section 2.1, please see highlighted lines 81 – 83, page 3.

The detection range depends on the echo power, which is related to the extinction/backscattering cross section resulting from the particle size distribution. Maximum particle size has big extinction/backscattering cross section, but because the probability of big particle is low, so the echo power due to fewer big particle could be not high. $V = \frac{5.5\times10^{-4}}{N_0 a_e^2}$ will decrease as the mean particle size increases.

2. Based on your simulations you should also discuss whether special specifications could be proposed for different radar wavelengths to be better suited for sand detection. This could in include the possibilities of increasing the radar sensitivity by increasing the pulse lengths or integration time. Can spatial resolution be exchanged with sensitivity?

***Authors' reply*:** Thanks for your very valuable suggestions. In this manuscript, the effective detection ranges of different bands microwave radar and lidar in dusty weather are investigated. And we want to make an appeal to use the radars and lidar at different weather stations combined to detect the dusty weather around cities. Based on the calculated results, it can be found that L-band radar and the C-band radar are suitable to detect server dusty weather like sand storm, while lidar is suitable to detect floating dusty weather. We added a case to calculate the echo power of C-band radar with two transmit powers, and it is found that the higher transmit power can increase the detection rang to see flowing figure (also Figure 7(b) in revised manuscript).



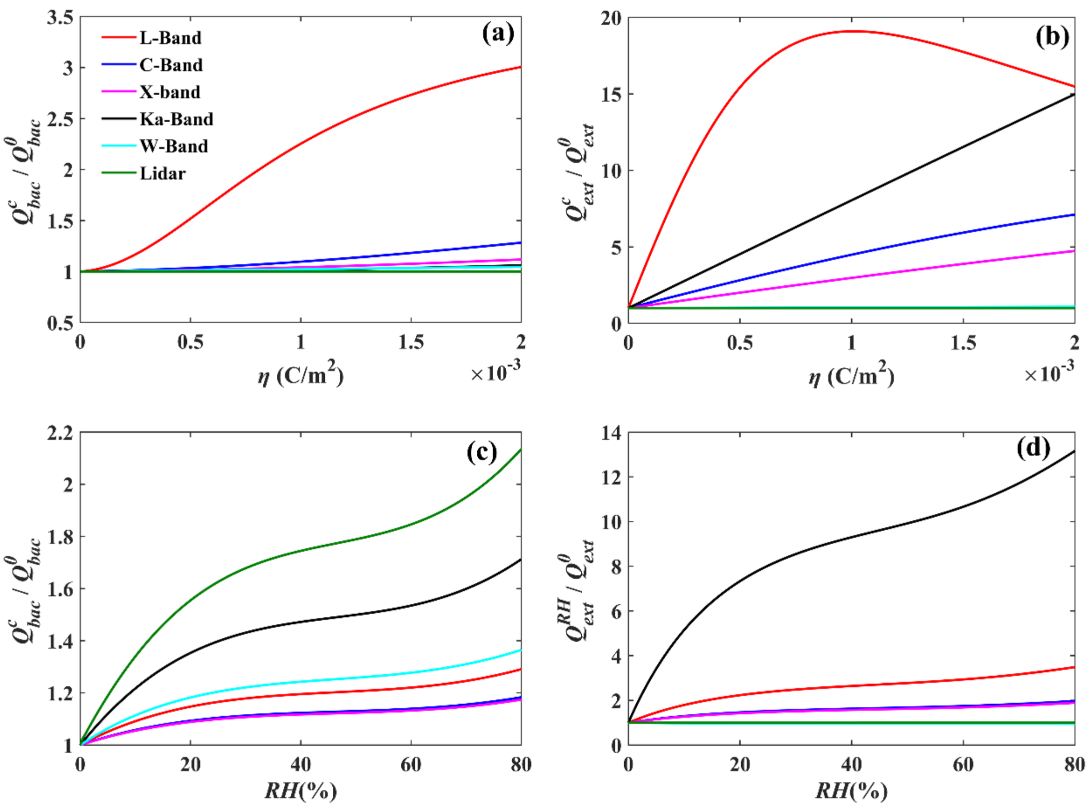
The echo power varying with the visibility V of dusty weather of C-band radar and lidar with two transmit Pt=25 kW and 50 kW, given R=10 km. The horizontal dash lines stand for the minimum detectable echo power, sensitivity, of each radar and lidar. Along green arrow, the echo power of radar or lidar is higher than its sensitivity.

3. You should elaborate more on the elements shown in Fig. 5 or leave it out.

Authors' reply**:** We have described in detail the elements shown in Figure 7 in the revised manuscript.

4. In Section 4 it would aid the understanding to discuss the increased backscatter and increased attenuation/scattering due to the surface charge and relative humidity. The assumptions on the vertical distribution of humidity remained unclear to me. Furthermore, the water vapor concentration or at least the assumed air temperature should be give. I would have expected an signal attenuation due the water vapor at least in the W-band by a few dB. I might have missed it in an earlier part, but it is unclear to me if the sand storm is horizontally homogeneous over the whole plane or if it just starts a certain range.

Authors' reply**:** According to your suggestion, the effects of excess charge carried by particles and relative humidity on the backscattering and extinction coefficients of microwave radar and lidar waves, as shown in following figures, also to see Figure 3 in the revised manuscript. It can be found that the relative humidity can enhance the backscattering/extinction coefficient. The effect of excess charge on the backscattering of waves with low frequency more obvious, while the effect of relative humidity on the backscattering of waves with high frequency waves more obvious. The attenuation is mainly determined by extinction coefficient. From following figure, it can be found that the extinction enhancement of W-band wave is not significant with *RH* increasing, therefore a signal attenuation due the water vapor at least in the W-band by a few dB is occurred when the wave goes through sand storm long path. We assume that the visibility of dusty weather is uniformly distributed along the transmission routes. And assuming that the radar site is in a sandy and dusty environment, only the transmission of radar waves in a sandy and dusty environment is considered. In addition, the effect of relative humidity on attenuation and backscattering considers the variation of equivalent dielectric constant of sand and dust particles at different relative humidity.



Effect of excess charge carried by particles and relative humidity on the backscattering coefficient and extinction coefficient, (a) variation of Q^c_{sca} / Q^0_{sca} with surface charge density, (b) variation of Q^c_{ext} / Q^0_{ext} with surface charge density, (c) variation of Q^{RH}_{sca} / Q^0_{sca} with relative humidity, (d) variation of Q^{RH}_{ext} / Q^0_{ext} with relative humidity. Superscripts *c* and 0 stand for the extinction/backscattering coefficient by charges particle and corresponding neutral particle.

5. Overall, I am missing a comment on the effect of gaseous attenuation for the simulations.

Authors' reply: Here we assume the dusty particles are full of detection path, and only the attenuation by dusty particles and water vapor are considered, and other gaseous attenuation is not considered in our calculation. The attenuation by water vapor is considered in the variation of the equivalent dielectric constant of particle with different relative humidity.

6. Besides the effect of particle charge and humidity, the authors should also discuss the following

How does the beam broadening and Earth's curvature affect the detectability of (shallow) dust storms?

***Authors' reply*:** The effect of beamwidth and earth curvature on radar echo power has been investigated by Chiou et al. (Chiou and Kiang, 2017). Their results show that considering the effect of beamwidth and earth curvature improves radar detection accuracy, however, from their calculations, the effect of beamwidth and earth curvature on the effective radar detection range is not significant because ignoring earth curvature only affects the accuracy of the detected particle concentration at different altitudes. We will investigate the effect of beam width, Earth's curvature in future in the scheme.

How good is the assumption of spheres for sand particles?

***Authors' reply*:** A study on the shapes of dust particles conducted by Ilan Koren et al. showed that most of dust aerosol particles were spherical, especially for small dust particles (Koren et al., 2001). Here the particles are small with mean radius 18.4um, therefore we calculate the particles as spheres.

Minor comments

L 45: Check if Elsheikh et al. (2017) is the correct reference for moisture inversions in sand storms.

***Authors' reply*:** We reconfirmed the cited literature. Elsheikh et al. (2017) is the correct reference for moisture inversions in sand storms. Elsheikh et al. point out that the *RH* increased drastically from approximately 20% to 70% during the dust storm measurement.

L 64: "Meteorological radars are usually used to detect the sandy dust weather". This sentence should be reconsidered. At least in my field of work, meteorological radars are primarily used to observe hydrometeors.

From my understanding, the term "radar" stands for "radio detection and ranging" and is therefore different to a "light detection and ranging" system. Thus, I am confused by the term "lidar radar". Instead, I would personally prefer the simple term "lidar".

***Authors' reply*:** We checked full text, and corrected the improper description and statement.

Fig. 1: As the yellow background does add nothing to the understanding of the figure, I would make it white.

Figures 2 and 8 should use one color bar each for all six panels. This makes the panels more comprehensible.

***Authors' reply*:** According to reviewer's suggestion, revised the figures to remove the yellow background of Figure 1 and use the one panels of Figure2 and Figure4. It looks much better.

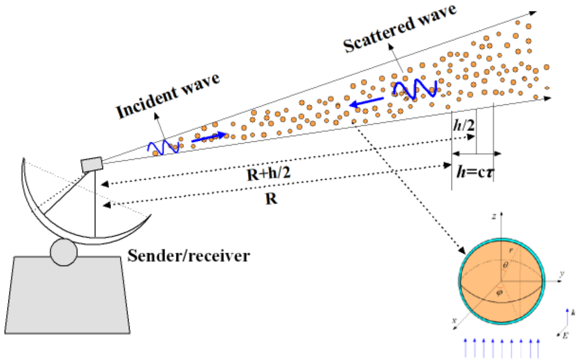


Figure 1. Schematic diagram of meteorological radar detecting sandy dust weather

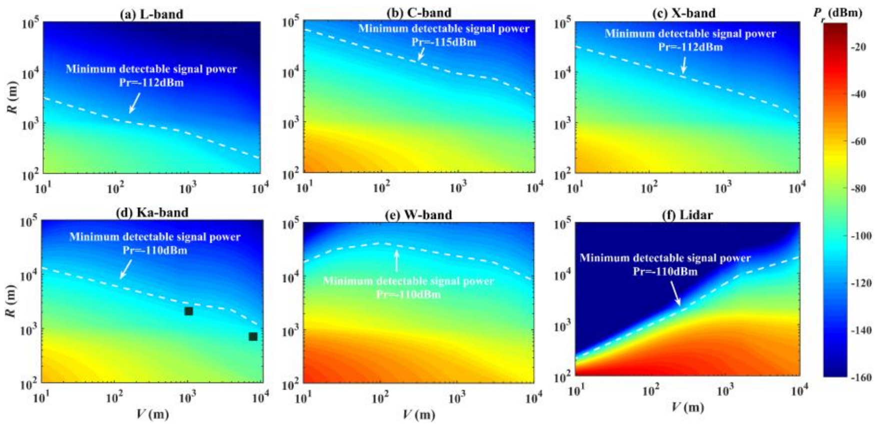


Figure 2

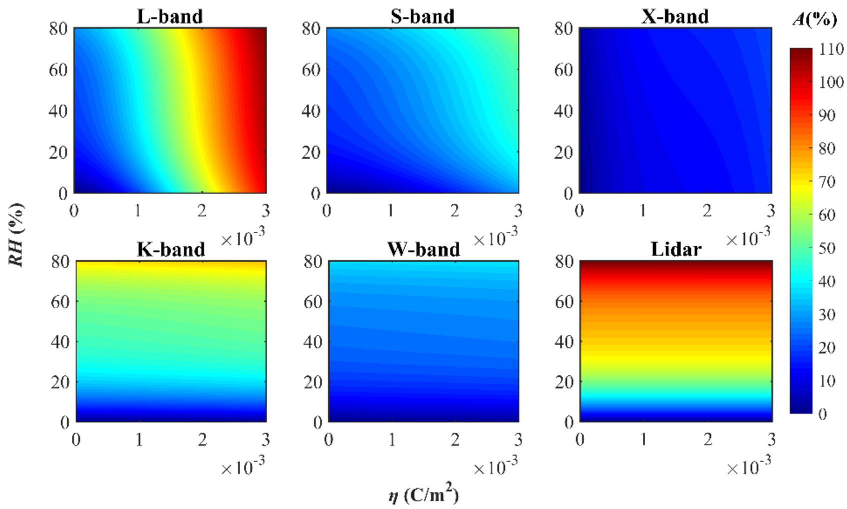


Figure 4

References

Chiou, M. M. and Kiang, J. F.: PWE-based Radar Equation to Predict Backscattering of Millimeter-Wave in a Sand-and-Dust Storm, IEEE Transactions on Antennas & Propagation, PP, 1-1, 2017.

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.