Response to anonymous referee # 3's interactive comment on the manuscript "A new parameterization of dust dry deposition over rough surfaces"

General comments

This paper investigates the question of the representation of dry deposition processes for dust particles and the influence of surface roughness on the deposition velocity. This is an important topic since the mass budget in 3-D dust model is largely under-constrained due to uncertainties in both emissions and deposition. The proposed parameterization is compared to the parameterizations proposed by Slinn (1980) and Slinn and Slinn (1982), that are widely used in 3-D aerosol models, and with experimental data, showing the improvement brought by this new parameterization. On original aspect of this work is to explicitly describe the relative influence of the roughness elements and of the bare fraction of the surface on the different terms involved in the deposition processes by analogy with the drag partition theory widely used to describe the erosion threshold over rough surfaces. The second original aspect is the comparison of this new parameterization with deposition velocity measurements performed in wind-tunnel for different surfaces with contrasted roughness properties. The paper is in general well written and well organized. In particular, the very detailed description of the main assumption is extremely valuable. Figures are clear and well described. A few clarifications on the assumptions made to establish the parameterization and on the sensitivity study (listed below) would make the results even more convincing. I recommend the publication of the manuscript after minor revisions.

Response: we'd like to thank the anonymous referee for the critical and insightful comments to our manuscript. Our reply is as follows.

Specific comments

1. -Page 8065 lines 10-16: the author argued that existing approaches have two deficits. It is not clear how or if the new parameterization provides a solution to the first deficit (gravitational settling).

Response: actually, the first deficit (gravitational settling) is taken into consideration by solving Eq. (1) analytically. The result is shown as Eq. (3), which also includes the resistances (r_a, r_g, r_s), but is not based on electrical-circuit theory and r_g is not considered as a parallel resistance anymore. The following comments will be added at the end of part 2.1:

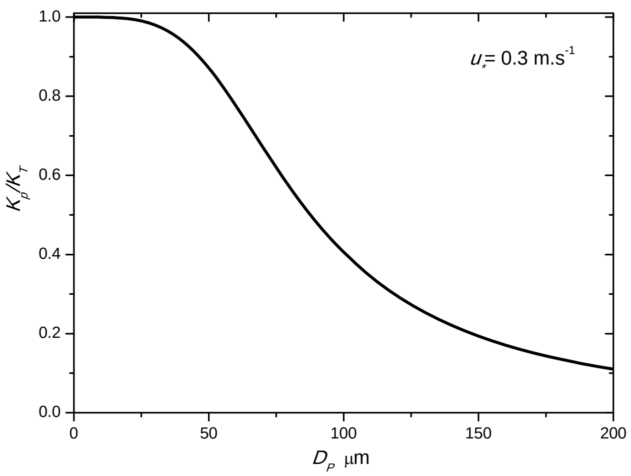
"Here, the expression of w_d [i.e. Eq. (3), an analytical solution of Eq. (1)] is not based on electrical-circuit theory and r_g is not considered as a parallel resistance anymore. So the first deficit we described in the introduction has been dealt with."

2. - Page 8065 lines 26-28: the comment on the results of the SS80 and S82 seems too severe regarding the figure 1...

Response: we have a somewhat different view. The results of SS80 and S82 are comparable with the experimental data for smooth surfaces (such as wood surface). That is because the deposition processes over smooth surface are relatively simple, and these physical processes are well represented in the SS80 and S82 schemes. But over rough surfaces, dust deposition is complex. The difference between the predicted data and experimental results is obvious, if the input parameters are evaluated according to the practical situation. The shortage of the existing schemes is caused by ignoring some physical processes, such as the lacking of surface parameterization. Although the difference between the scheme and experiment can be reduced by adjusting some input parameters, the adjustment is often unreasonable and has no physical basic. That is why the existing schemes perform relatively poorly for rough surfaces.

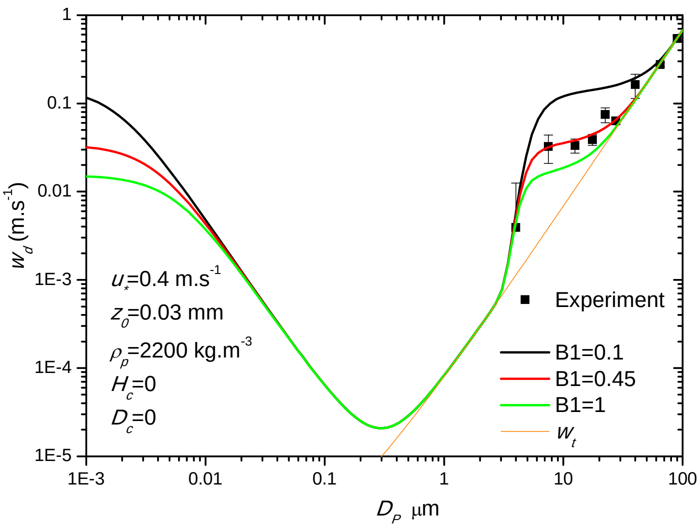
3. - Page 8068 line 9: the choice of the value of 1 for α and σ as u_* should be further justified.

Response: α and σ are the parameters for Eq. (6) which is proposed by Csanady (1963) to describe the trajectory-crossing effect of heavy particles in the atmosphere. α is considered as a constant, but the precise value of α is not certain. α is normally set to 1 in the discussions of Csanady (1963), Shao (2008) etc. σ is originally defined as the standard deviation of the turbulent velocity. If the turbulence is isotropic, it is acceptable to consider σ as the friction velocity u_*. For simplicity, we take the choice of the value of 1 for α and σ as u_*, which is not very precise but can describe the behave of K_p/K_t well (close to 1 for small particles which can follow the air stream well and reduced for large particles which are hard to follow the air movement because of particle inertia, as shown in the following figure).



4. - Page 8069, line 1-4: B1 has been determined from the wind-tunnel measurements. Is it a sensitive parameter?

Response: B1 only applies to smooth surface. The value of B1 is determined from the wind-tunnel measurements over sticky-wood surface. As shown in the following figure, B1 is sensitive for the particle less than 0.01 μm and for the particle with size from 3-50 μm.



5. - Page 8071 line 10: the impaction efficiency is taken from Petroff et al. (2008) and is assumed constant whatever the roughness elements. Should it vary depending on the type of surface, for example, stone versus vegetation?

Response: the impaction efficiency E^{im} proposed by Petroff et al. (2008) is based on the results of three measurement campaigns on isolated cylinders (Ranz and Wong, 1952; May and Clifford, 1967; Starr, 1967). E^{im} represents the probability for the particles collected by the roughness element (normally considered as a cylinder in scheme). E^{im} is not constant. It is depended on the size of roughness elements and is of course varied for different surface types. Additionally, the surface type also affects the other parameters in the scheme, such as R which relates to surface texture, A_{in} which relates to surface micro-roughness and so on.

6. - Page 8071 line 13: is it really relevant to take into account particle growth for mineral dust? Are the parameterization from Fitzgerald (1964) and Gerber (1985) appropriate for such particles?

Response: we take into account particle growth to the make the new scheme have a potential to describe the deposition for other kind of particles, such as sea-salt and sulphate aerosols. If the particles do not satisfy the requirement of particle growth mechanism, we should set RH=0% or $D_{p,\delta}$=D_p to exclude the effect of particle growth.

7. - Page 8075 line 8: the definition of β, that can be found in table A1, should be given here. In addition, arguments on the choice of a unique value should be given. Based on wind tunnel measurements, Walter et al (Boundary Layer Metorol., 2012) estimated this value to 137 for blocs and 93 for vegetation elements.

Response: accepted. We will add the definition of β and add the arguments on the choice of a unique value in the revised version.

8. - Page 8076-8077: in the description of the comparison between the new parameterization and the measurements, more details on what parameters really makes the difference from one surface to the other should be given, in particular for the parameters that will further used in the sensitivity analysis.

Response: we will improve the presentation of this part to highlight the reasons (about input parameter) for the difference of deposition velocity from one surface to the other.

9. - Page 8076 line 5-15 : it is quite surprising to read that sand grains are treated as individual obstacles, since they does not really fits the representation of figure 2, and especially when the final sentence states that sand grains are smooth. The size of the sand grains should be given explicitly. It is stated that in this case hc=30.Z0 and three values of Z0 are given. I cannot imagine that the size of the sand also changes.

Response: in our opinion, the sand surface fits the representation of figure 2, just the height of the obstacles is a little small (half of the diameter of sand particle, $h_c = D_{sand}/2$). Comparing to dust particles, the size of sand is relative big and the sand particle could be treated as a roughness element (or collector). We states that sand grains are smooth, which means there is no micro-roughness-element, such as hair, over sand particle and the surface of sand particle is supposed smooth (doesn't mean sand surface is smooth). In this case, we set $h_c=D_{sand}/2$. "h_c=30.Z_0" is applied on water surface but sand surface.

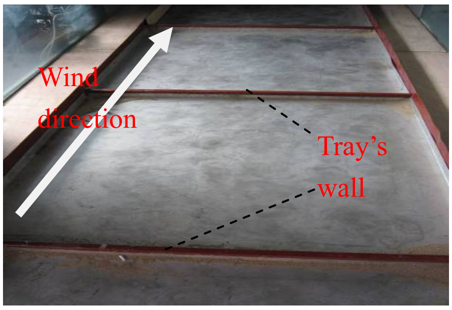
10. - Page 8076 line 22: it is difficult to imagine trees in a wind tunnel. May be "Shrubs" or "plants" would be more appropriate.

Response: we'd like to change it to "plants".

11. - Page 8076 line 27 - page 8077 line18: this part of the discussion is not clear, in particular concerning the role of bubbles and spay droplets. Are the wind tunnel measurements made at such wind velocity that it creates waves on the water surface that produce such bubbles and sprays? In this case, there would be a change in the roughness length (mentioned as constant and low in table 3). So even if the parameterization fits very well the measurements, I am not convinced by the discussion and by the final sentence ("We have shown ... droplets".

Response: this was a question puzzled us in the experiment. Finally, we find the bubbles and spay droplets or constant roughness length both relates to the trays (shown as the following picture) used to fill the water in the experiment. Actually, the bubbles and spay droplets are caused by the hitting of the water waves on the wall of the trays. And actually, the wind profile is mainly affected by the wall of the trays. That's the reason why roughness length is almost a constant.

We will add this information in the discussion to make it convincing.



12. - Page 8077: this sensitivity analysis is very welcome at this point of the manuscript and very interesting. However, it would be more convincing with some arguments on the selected range of values for the different parameters. As an example, the roughness element size vary from 1 to 10 mm, which is very low, especially compared to the height of the roughness elements fixed to 150 mm. This makes very long and thin obstacles: what kind of surface can is it supposed to represent? On the opposite, the range of roughness density is very large. Similarly, particle density has been taken from 1000 to 5000 kg.m^{-3}: Is it realistic compared to the density of typical minerals composing mineral dust?

Response: we'd like to add some arguments on the selected range of values for the different parameters (or change some selected range).

Fig. 3 is only a conceptual picture. h (or h_c) is actually the height of collection layer in where surface collects exist. d_c is the typical size the surface collect. As an example of plants, it is possible that h_c is several meters (the height of the plant) and the size of d_c (the size of branches or leaves) is several millimeter. The purpose of taking a large range of roughness density is to illustrate the whole change of surface roughness with increasing λ, from smooth to rough, and then back to smooth. We take particle density from 1000 to 5000 kg.m^{-3} to extend the application of the scheme to some other aerosol, including the heavy metal aerosol.

13. - Page 8079 line 20-21: please, comment the figures or remove them.

Response: we will remove Fig. 6 which looks unnecessary here.

14. - Page 8010 line 5-7: Additional test on different or larger range of roughness element dimensions could also be mentioned to treat deposition on urban surfaces or forest.

Response: we will add test of roughness element dimensions in larger range.

Technical corrections:

1. - page 8068 line 3: does "neutral particle" refer to their electrical charge?

Response: yes

2. - Page 8073 line 20: "depended" should be replaced by "dependent"

Response: accepted

3. - Page 8075 line 24: "absence" should be replaced by "absent".

Response: accepted

4. - Page 8078 line 8: in the sentence "dust deposition is suppressed ..", replace "suppressed by "negligible", for example.
Response: accepted

5. - Page 8078: line 13-16 : It should be clearly stated that it is not very sensitive.
Response: accepted