Answer to RC2 comment on the manuscript "**AerSett v1.0: A simple and straightforward model for the settling speed of big spherical atmospheric aerosol.**"

Jan. 13, 2023

We are grateful to Anonymous Reviewer #2 for his/her careful Review of our manuscript.

1 General comments

In this scientific paper authors present an alternative methodology for the calculation of the terminal velocities of spherical particles beyond the Stokes regime. The method includes a mathematical expression that approximates the non-analytical solution of the 1-D (vertical) equation of motion by circumventing the utilization of an iteration method which is originally needed. They show that the error of the methodology is acceptable with its maximum value to be around 2% for particles up to 1000 μm. The paper is well-written, well-organized, with a straightforward abstract and fulfills the main goal of the article. Although, some adjustments should be done in the Introduction section. The results are clearly presented in good-quality graphs and the conclusions are well established.

I suggest the publication of this work after some minor revisions.

We are grateful to both Reviewers for their positive appreciation of our manuscript and for their comments, helping us propose a much improved version of the manuscript. In particular, we have added two new sections to address the shortcomings identified by the both Reviewers in the discussion:

Section 5: Inclusion of the slip-correction factor

This section addresses one of the the main comments of both Reviewers (Reviewer 1: "Lines 41-42. Mallios et al. (2020) as well as Drakaki et al. (2022) include the slip correction factor in the drag equation, because it is crucial for particles with Reynolds numbers less than 1. Why do the authors have omitted this factor?", Reviewer 2, "Line 60: For Re¡0.1 the consideration of free-slip correction should be added as it is described in Drakaki et al. (2022) and Mallios et al. (2020). Why did you omit it in both Stokes and Clift and Gauvin expressions? Could the consideration of the free-slip correction possibly change the methodology? By not including the slip-free correction, makes the methodology valid only for $Re \geq 0.1$."), which as they correctly assert would be a critical limitation of our method. Therefore, we present a modified version of our method to explicitly include this effect.

Section 6: Implementation and computational efficiency

This new section also addresses a request by both Reviewers (Reviewer 1: " What is the computational time gain against robust iterative numerical methods that can solve more general problems?", Reviewer 2, "Can you provide an estimation of the computational benefit of the method?"

We feel that with these additions, and rewriting the introduction that was found confusing by both Reviewers, this paper has improved considerably and now provides an out-of-the-box solution to modellers needing to estimate correctly the settling speed of spherical aerosol for the entire range of atmospheric conditions and relevant diameters for atmospheric aerosols.

Also, please note that there was a problem with the transcription of our numerical method in the paper: in the formulae describing our numerical method, a coefficient was mistakenly written as 0.4335 instead of −0.4335. There was no problem in our numerical calculations or in the corresponding scripts and figures, only on their transcription into litteral formulae in the paper. This has been fixed in this new version.

2 specific comments

2.1 Section 1

Introduction in general: I suggest the authors to change the order of the first two paragraphs. This will help the reader to understand the topic's background and prepare him for more detailed and specific information that is given later. Also the introduction should include more papers of prior research on large dust particles.

As also noted by Reviewer 1, the outline of the introduction was indeed confusing, navigating back and forth between different topics. We used the detailed suggestions by Reviewers 1 and 2 to reorganize and add more substance to the Introduction where needed. the introduction is now organized following a clearer outline.

First, we explain why it is important to calculate accurately the settling velocity of aerosols (as it governs dry deposition, which is their main sinks)

Then we briefly introduce some of the bibliography on giant dust particles, without the pretention to give a bibliographic overview of this topic (which as precised in the revised version is beyond the scope of our sudy: the reader is referred to other studies for more bibliography). The point of this paragraph is to justify that:

1. Giant dust particles exist in the atsmosphere
2. they are not only a curiosity, but they also play a geophysical role

After that, we put another paragraph explaining why modelling giant dust particles requires to take intro account large-particle correction factor to the Stokes law, and how this has been done so far.

When this is done, we present the goal of the paper, and its outline.

In particular, we now present the precise goal of the papar towards teh end of the revised introduction, after giving more information on the context of the study and why we feel our work is useful in this context.

Lines 10-11: What is large-particle correction? Authors should introduce that term in order a less engaged reader can understand better the meaning of the sentence.

With the reorganisation and the rewriting of the itroduction, the introduction of "large-particle correction" now comes later, and with a more detailed explanation of the term:

"The sedimentation speed of giant particles deviates substantially from the Stokes law, an effect that can be taken into account using mathematical formulations known as large-particle corrections. Usually, these large-particle corrections are performed by using empirical formulations of the drag-coefficient C_d as a function of the Reynolds number Re (typically the one provided by [Clift and Gauvin, 1971]), and numerically solving an equation to obtain an estimate of the settling speed v_∞ as a function of the characteristics of the particle and of ambient air." etc. etc.

Line 16: Please give the definition of giant particles.

The definition of the giant mode for dust particles according to [Ryder et al., 2019] is now given in the second paragraph of the introduction.

Lines 16-17: References are needed here.

In the revised version, the second paragraph in the introduction gives a bit more bibliography and context on giant dust particles. However, since this topic is not the heart of the manuscrip topic (but needed to justify why our study may beb useful), we did not want to increase too much the focus on this bibliographical field. At the end of this paragraph, we orient the reader towards some recent studies of the field for a more complete bibliography: "For a more complete bibliography, the reader is referred to van der Does et al. (2018), Ryder et al. (2019) and Drakaki et al. (2022)."

Lines 18-19: Why do we care about the missing from the models coarse dust particles. How do they affect the physical processes in the atmosphere?

Some more arguments have been added to answer this question in the revised version: "The contribution of the giant mode is substantial, at least over the Sahara: Ryder et al. (2019) shows that not taking into account giant dust particles over the Sahara results in underestimating mass concentration by 40%, and extinction by as 18% for shortwave radiation and 26% for longwave radiation. Dust particles with diameter up to 100 µm are present not only above the Sahara (Ryder et al., 2019) but have also been observed, far away from emission sources.". As above, the reader could refer to the cited publications for more information on this point.

Line 26: The authors state that Drakaki et al. (2022) use Clift and Gauvin (1971) correction and performed the bisection method once for each model size bin. The word "once" is a little confusing, since viscosity depends on pressure and temperature, which changes at each time step and in each model grid box. Thus, the terminal velocity is calculated accordingly at each time step, in each model grid box and for each model size bin, adapting the bisection method. This makes the code even more time consuming.

We are grateful to the Reviewer for this piece of information we had actually misunderstood. The precision brought by the Reviewer has been transcribed in the paper:

"An exception to this is the recent development exposed by [Drakaki et al., 2022] in the GOCART-AFWA dust scheme of WRFV4.2.1. In that study, the [Clift and Gauvin, 1971] drag coefficient correction is taken into account by a bisection method, performed at each time step, in each model cell and for each model size bin to calculate the settling speed as a function of the particle properties and the atmospheric conditions."

Line 51: The expression for air viscosity is missing.

It is now included (Eq. 4 in the revised version)

Line 60: For $Re < 0.1$ the consideration of free-slip correction should be added as it is described in Drakaki et al. (2022) and Mallios et al. (2020). Why did you omit it in both Stokes and Clift and Gauvin expressions? Could the consideration of the free-slip correction possibly change the methodology? By not including the slip-free correction, makes the methodology valid only for $Re \geq 0.1$.

We fully agree with this comment, and that this limitation restricted the use of our method greatly. Therefore, as described in the "General comments" section, an extension of our method to include the slip-correction term is now the object of Section 5, and the method is modified accordingly in the conclusion.

Line 61: Please describe in detail the iterative method you used. Also in line 68.

The iterative method (which was actually only suggested in [van Boxel, 1998] but not described) is now described in the beginning of Section 6 of the revised manuscript.

Line 141: Please define the exact ranges that the expression is valid.

We have added the following precision: "valid for all spherical particles with $D < 1000\,\mu$m and at least from the surface to $p = 200$ hPa (Figs. 3b and 4)"

Line 142: Can you provide an estimation of the computational benefit of the method?

See the General comments section. Since both Reviewers indicated that this was missing, we have added Section 6 to perform this calculation.

Best regards,

The Authors.

References

[Clift and Gauvin, 1971] Clift, R. and Gauvin, W. H. (1971). Motion of entrained particles in gas streams. *The Canadian Journal of Chemical Engineering*, 49.

[Drakaki et al., 2022] Drakaki, E., Amiridis, V., Tsekeri, A., Gkikas, A., Proestakis, E., Mallios, S., Solomos, S., Spyrou, C., Marinou, E., Ryder, C. L., Bouris, D., and Katsafados, P. (2022). Modeling coarse and giant desert dust particles. *Atmospheric Chemistry and Physics*, 22(18):12727–12748.

[Ryder et al., 2019] Ryder, C. L., Highwood, E. J., Walser, A., Seibert, P., Philipp, A., and Weinzierl, B. (2019). Coarse and giant particles are ubiquitous in saharan dust export regions and are radiatively significant over the sahara. *Atmospheric Chemistry and Physics*, 19(24):15353–15376.

[van Boxel, 1998] van Boxel, J. (1998). Numerical model for the fall speed of raindrops in a rainfall simulator. Technical Report 1998/1, I. C. E. special report.