Response to Anonymous Referee #1

RC1: 'Comment on egusphere-2026-2931', Anonymous Referee #1, 26 Jun 2026
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This manuscript applies a classical electrostatic theory to the collision and aggregation of charged mesospheric ice particles with anthropogenic smoke particles (ASPs) originating from re-entering space debris, deriving the minimum and maximum relative velocities that permit stable aggregate formation. The authors then use this to show that abundant or high-dielectric anthropogenic oxides such as Al_2O_3 and TiO_2 are likely to dominate aggregate formation, an interesting finding that can tell experimentalists what to look for. The study is timely and clearly written, and I recommend publication after consideration of the following minor comments.

The authors sincerely thank the anonymous referee for his/her careful evaluation and for recommending our manuscript for publication. We have considered and addressed the reviewer's minor concerns. The point-wise responses to the reviewer's comments are as follows. To facilitate the referee, the major changes are highlighted in magenta in the revised version of the manuscript.

Minor comments

Abstract (line 4): Add a note of caution about the extent to which classical electrostatic theory can be applied to such small particles.

Response

We have added "nano-meter-sized" before ice particles and remnants of space debris. Please see: Line 3.

Abstract (line 8): Clarify what is meant by "aggregation velocities." The meaning becomes clear after reading the article, but it is unclear in the abstract.

Response

We have modified the statement "For most particles, the velocity range of aggregation is from a few m/s to several tens of m/s, where smaller particles may need significantly higher velocities to form stable aggregates."
Please see: Lines 7-9.

Lines 67–69: The statement that particles with charges of the same sign can experience a strong attractive interaction is confusing on first reading. Make clearer that this arises from polarisation, and that it concerns composed particles. Consider phrasing it as "two uncharged particles, or even two particles of the same charge."

Response

We have modified the statement as "Two particles with charges of the same sign will experience a repulsive Coulomb force at certain separation distances. However, at small separations, their dielectric properties lead to a strong attractive interaction. This attraction arises from the polarization of surface charge between like-charged particles, leading to regions of positive and negative surface charge density on one particle due to the influence of the other."
Please see: Lines 68-71.

Lines 84–86: Explain and justify this assumption better.

Response

We have modified the statement as "In the MLT region, the density of dust particles is comparable to that of the ambient plasma electrons and ions. The dust can act both as individual particles and collectively. Under the plasma

conditions present in the MLT region, the dust acquires charges through plasma particle capture, photodetachment, and photoionization."
Please see: Lines 85-89.

Line 90: Change "usually" to "is believed to," or add a reference.
Response
We have modified "usually" to "are believed to" and also added a reference [Rapp, M. and Lübken, F.-J.: Modelling of particle charging in the polar summer mesosphere: Part 1—General results, Journal of Atmospheric and Solar-Terrestrial Physics, 63, 759–770, 2001]
Please see: Line 91.

Line 123: Briefly explain what the coefficient of restitution is.
Response
We have added the sentence "where k_r is the coefficient of restitution, which quantifies how much kinetic energy remains after a collision. It determines the elasticity of collision, which varies according to the composition of a particle." to accommodate the reviewer's suggestion.
Please see: Lines 125-126.

Figure 1: Consider labelling the x-axis "separation distance" rather than just "s."
Response
We have modified "s" to "separation distance". Please see: Figure 1.

Figure 2: Consider adding a panel for the colors; show the minimum-to-maximum velocity range as a band rather than two differently coloured lines.
Response
We have added the band within the two differently coloured lines. Please see: Figure 2.

Figure 2 (caption, lines 95–96): State clearly that we do not know what sizes ASPs may have, so 1 and 5 nm are assumptions. Some limits might be obtained from the sedimentation velocity and the amount of incoming material, so these values are reasonable — but it should still be made clear that the actual sizes are unknown.
Response
We have revised the sentence as "Although the actual ASP size distribution is currently unknown, we assume various representative oxides with radii ranging from 1 to 5 nm."
Please see: Lines 96-97.