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Atmospheric Chemistry and Physics Discussions

Interactive comment on “The influence of surface charge on the coalescence of ice and dust particles in the mesosphere” *by* Joshua Baptiste et al.

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This paper is about electric charge effects on the coalescence of small particles, during collisions between them, in the Earth’s mesosphere and lower thermosphere, at temperatures around 150K. What is new is the treatment of the effects of point charges on particles of low dielectric constant, on the aggregation probability in such collisions. There has been much previous work in atmospheric sciences on collisions of small charged particles; with each other, with water droplets, and between water droplets. Since this paper is applying results from chemical and colloidal physics to the atmosphere, it would be appropriate to refer to previous work in that field. The attraction between a charged dielectric sphere to a charged conducting sphere was treated in 1976 by Grover (Pure and applied Geophysics, 114, 521-539), for both the presence

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Discussion paper

and absence of an arbitrary external electric field. Dielectric constants ranging from zero to infinity were considered, demonstrating that for dielectrics of ε > 80, including water and ice, the results for spherical particles are the same as for conducting spheres. A shape factor applied to non-spherical particles allows them to be treated as spheres. Much work has been done on conducting spheres, as reviewed in the 1998 book by Pruppacher and Klett (Microphysics of Clouds and Precipitation, 954 pp., Klewer). Their Chapter 11 is on aerosol, including electrical effects, and Chapter 18 covers collisions between electrified aerosol and larger particles, treated as conducting spheres. A recent treatment is by Zhang (J. Geophys. Res.-Atmos. 124, 13105-13126). The treatment here of the effects of 'polarization of surface charge' is equivalent, for conducting spheres and dielectrics of ε > 80, treatments of collisions in terms of 'image charges'. The calculations of aggregation probability presented here are for particles of the same sign charge, and in many cases the values found are very small. Thus same-sign charge collisions form only a small part of the overall process of coagulation in the atmosphere, since encounters between particles of opposite sign charge, and with neutral particles, have aggregation probabilities of unity. In the atmosphere dust particles with both positive and negative charge are present, from attachment of positive and negative air ions to the particles. The air ions are produced by the cosmic ray flux in the mesosphere and lower thermosphere, and are present in essentially equal numbers (see comment below), giving rise to approximately equal numbers of positively and negatively changed aerosol particles. So most of the aggregation there will be due to oppositely charged or charged and neutral particles, and the same-sign encounters will be quite a minor contribution. There are a number of problematic issues with the treatment of even that component, as follows: With reference to lines 30 to 38: At low and mid-latitudes, in the mesosphere from 60-90 km altitude, the dominant source of ions is galactic cosmic rays, not energetic electrons > 10 keV or photoelectron processes. The electrons produced by cosmic ray impact immediately attach to molecules, and the result is both positive and negative air ions, which by attachment to aerosol particles produce comparable numbers of positively charged, negatively charged, and neutral aerosol particles. Also, above 90 km near the auroral zones, it is secondary electrons produced by the 1-10 keV primaries, not the primaries themselves as implied. The keV electron precipitation is intermittent, and a negligible source of ionization in the mesosphere. Line 52. The phrase 'or predictions' is inappropriate in view of the earlier of the work as early as Grover (1976) showing image charge attraction with dielectrics. Line 70. Add 'attachment of an ambient air ion, or' after 'for example'. Line 84. The brief discussion is section 5, not section 4. Line 105. The use of 'CR' as a symbol for the value of coefficient of restitution is unfortunate. This has led to CR2 in line 106, equation (3) and elsewhere. Using two capital letters is poor style and an impediment to interpretation when squared. A single or subscripted capital should be used. Line 125. A reference for the source of this equation is needed. Line 131. That particles with the same amount of charge 'should' have dissimilar sizes for size dependent attraction is not a new result from Bichoutskaia et al. It has been known for decades from work on conducting spheres that only for large charge differences or large size ration can there be a significant attractive force due to image charges to oppose the Coulomb force. From the 1964 work of Davies (Quart. J. Mech. and Appl. Math. 17, 490-511) and 2004 work of Khain et al. (J. Appl. Met., 43(10), 1513-11529) it follows that for equal charges on equal sized spheres the forces due to the image charges induced by the spheres on each other exactly cancel out the Coulomb force as the separation of the spheres goes to zero. Line 154. The coefficient of restitution 'CR' is taken as 0.9. For CR = 1.0 the aggregation probability would go to zero. What is the justification for this apparently arbitrary value? Line 164. Yes, a uniform charge distribution definitely would be more appropriate. Why is an inappropriate distribution used? Also, with reference to the Figure 3 and the charges of -2e on the oxides used for the calculations, the second charge is in the same location as the first charge. This is highly unlikely, and its use in this location negates the value of the calculations on this assumption.

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