Dusty plasma diffusion in PMSE with the growth of aerosols

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Polar Mesosphere Summer Echo (PMSE) is the phenomenon of very strong radar echo with the radar frequencies from 8 MHz to 1 GHz occurring at the altitudes close to the summer polar mesopause. It is widely accepted that small-scale structures in electron density are responsible for the PMSE. To study the evolution of small-scale structures, ambipolar and multi-polar diffusion models [1,2] were developed previously. The previous models treated aerosol (ice) particles either as fixed-charge dust [1] or as multiple-charge-state dust using chemical rate equations [2], in which the growth of the ice particles has never been considered.

We developed a multi-polar diffusion model of dusty plasma, which is based on the average dust charge with charge variation and accounting for the growth of the ice particles in the PMSE region. We assumed that the dusty plasma consists of electrons, positive ions, and negatively charged dust (ice) particles in the background of neutral air with super-saturated water vapor. The diffusion equations are established and solved numerically. The dependence of diffusion time scales on the initial scale lengths of the dust density distribution is estimated and shows good agreement with the numerical results.

For typical parameters in summer polar mesopause, the numerical results show that the evolution of the dusty plasma undergoes the initial charging process (tens of seconds), then the ambipolar diffusion process on ion time scale (hundred seconds, with immobile dust particles), and the multi-polar diffusion on dust time scale (about 10^4s), until the spatial inhomogeneity gradually decreases and disappears.

Furthermore, the results show that the growth of the ice particles tends to prolong the diffusion time scales and cause the positive correlation (contrary to negative correlation as in the case without considering the growth) between the electron and ion densities, i.e., both decrease in the electron and ion densities.

In addition, the effect of the gravity and neutral air wind tends to shift the density structure in the vertical direction, as shown in figure 1. Without considering the dust growth, the upward neutral wind overcomes the gravity and causes the upward drift of the structure. As the dust particles grow in time, the gravity eventually dominates over the neutral wind, which results in the initial upward and final downward drift of the density structure. The spatiotemporal evolution of the small-scale density structure (electron density is anti-correlated with dust density) may be applicable to the interpretation of the observed evolution of the PMSE.

References

[1] Hill R. J. *J. Geophys. Res.*, 1978, **83**, 989.
[2] Lie−Svendsen Ø, Blix T A, Hoppe U P, and Thrane E V. *J. Geophys. Res: Atmospheres*, 2003, **108**, 8442.

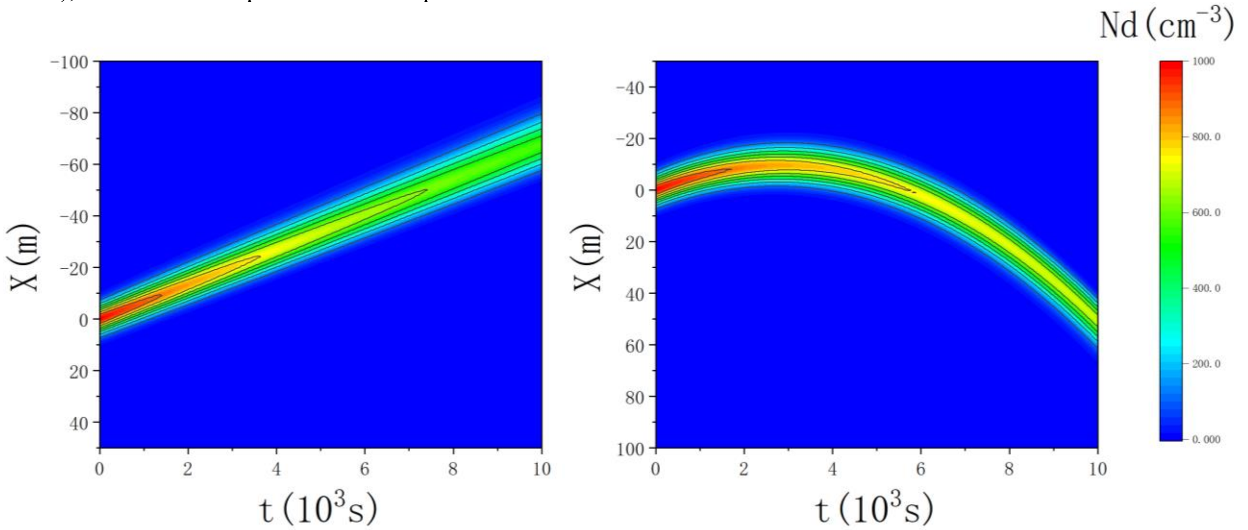

Figure 1. Spatiotemporal evolution of the small-scale structures in the dust density distributions without (left) and with (right) the consideration of the dust particle growth. Numerical results indicated that the dust growth tends to slow down the diffusion and causes the vertical drift of small-scale structure from up- to downward direction. Initial dust density profile is assumed Gaussian with n_{d0} =10^3 cm^{-3} and a width σ=5 m. The upward velocity of the neutral wind is taken to be 3 cm/s. The plasma and neutral air parameters are taken at the polar altitude 85 km.