Active perturbation of plasma irregularities associated with charged mesospheric dust

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Polar mesospheric summer echoes PMSEs are strong radar echoes in the 50 MHz to1.3 GHz frequency range produced by scattering from electron irregularities in the earth's mesosphere. The electron irregularities believed to produce PMSEs result from electron charging onto subvisible dust. This dust consists of ice particles created due to the cold temperatures in this region of the atmosphere. Recently, experimental observations have shown that PMSEs may be modulated by radio wave heating the irregularity source region with a ground-based ionospheric heating facility. Early experiments showed that the PMSE strength may be initially suppressed after the turn-on of the radio wave heating. It was also recently observed that PMSE strength may be enhanced for a time period after turn-off of the radio wave heating. This has been termed 'PMSE overshoot'. An understanding of the temporal behavior of PMSE strength during radio wave heating shows great promise as a diagnostic of the mesospheric dust layer. Early theoretical modeling considered the two primary physical processes causing the PMSE modulation, electron diffusion and dust charging, separately. Also the Boltzmann approximation, which neglects finite diffusion time effects, has been invoked. Since the relative timescales for dust charging and ambipolar diffusion may be comparable, depending on the mesospheric conditions and irregularity scale-size, important temporal behavior is not incorporated in recent models. This work describes a new model that incorporates both finite diffusion time effects as well as dust charging. The model utilizes fluid ions described by continuity and momentum equations, electrons whose behavior is determined from quasi-neutrality, and the charged dust grains are described by the standard Particle-In-Cell PIC method. A statistical model is used to implement discrete charging onto the dust grains. The electric field is calculated by using a zero net current density assumption. The model has been used to investigate temporal behavior of electron irregularities during electron temperature enhancement associated with radio wave heating over a range of dust and plasma parameters. The model predicts that the temporal behavior of the irregularities during radio wave heating depends on the ratio of the electron-ion ambipolar diffusion time to the dust particle charging timeτ_{dif}/τ_{chg}. Due to the dependence of τ_{dif} on irregularity scale-size, these results have important implications for observations of PMSE modification at different observing radar frequencies. Therefore new possibilities may exist for diagnosing the dust layer with radio wave heating which are discussed.