Studies of Plasma Instabilities on Specular Meteor Trail Decay Times

Freddy R. Galindo[1], Julio V. Urbina*[1], Steven J. Franke[2], and Lars Dyrud[3]

[1] Communications and Space Sciences Laboratory, The Pennsylvania State University, University Park, PA, USA

[2] Department of Electrical and Computer Engineering, University of Illinois, IL, USA

[3] EagleView, Washington, DC, USA

Meteor studies concerning the evolution of meteor trails demonstrate that decay times of underdense specular meteor reflections can be affected by an array of phenomena that include the Earth's magnetic field, plasma instabilities, attachment of electrons to neutral or charged dust, presence of large icy particles, among other things. The characterization of each of these processes is, therefore, crucial to correctly estimate diffusion rates from experimental observations of meteor decay times. In this paper, we report the effects of plasma instabilities on the decay times of underdense specular meteor trails. These studies are divided in three stages. In the first stage, we developed a numerical model for underdense specular meteor echoes that includes, for the first time, the effect of plasma instabilities on the creation and evolution of these meteor trail echoes, i.e. inclusion of turbulent diffusion. The numerical model can also simulate meteor trail echoes without the effect of plasma instabilities for purposes of comparison, i.e. non-turbulent diffusion. In the second stage, we characterize the effect of plasma instabilities on underdense specular meteor trail echoes. This characterization is implemented by comparing diffusion rates extracted from simulated unstable trails against those diffusion values obtained from simulated stable trails. The effect of plasma instabilities on specular echoes is particularly important in the estimation of mesospheric temperatures since these temperatures are inferred assuming that diffusion rates under produced by stable trails. Accurate meteor diffusion values are also important to implement reliable meteor scatter communication systems. In the third stage, both experimental and theoretical meteor data are carefully studied to verify these plasma instabilities effects. The simulations also indicated that if both turbulent and non-turbulent diffusions are the only mechanisms expanding the trail, the underdense specular meteor trail echo could exhibit a double decay time. This finding was validated using observational meteor echoes from the University of Illinois SkiYMET radar that exhibit a double decay pattern against those echoes that display a single decay pattern. An additional outcome of our studies is that meteor events with double decay time could also represent a unique opportunity to estimate diffusion values parallel and perpendicular to the Earth's magnetic field.