# Meteor Electric Fields: Implications for E-Region Radar Observations

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A meteoroid penetrating the Earth's ionosphere leaves behind a trail of dense plasma observed by radars. Radar echoes caused by meteors constitute a significant part of the entire radar clutter from the E-region ionosphere. Electron density irregularities that give rise to these echoes are partially caused by destabilizing polarization electric fields which are developed in or nearby the meteor plasma trail. To model the radar echoes for diagnostics purposes, we need to properly understand the underlying physical cause, i.e., macroscopic electric fields. In this talk, we will present quantitative models of the meteor-induced polarization electric fields in the presence of the external magnetic and DC electric field in the E region.

Low-power, small-aperture radars detect localized specular echoes which occur only when trail lies perpendicular to the radar line-of-sight. High-power, large-aperture VHF and UHF radars observe both head echoes, i.e., short duration signals traveling with the ablating meteoroids, and non-specular echoes, i.e., long duration signals persisting for a relatively long time in a broad altitude range within the E-region ionosphere. We have argued that non-specular echoes result from radar signals scattered from turbulent electron density irregularities generated by E-region plasma instabilities. Modeling of specular and head-echo radar echoes requires knowledge of spatial/temporal distribution of the trail plasma density, while modeling of non-specular trails requires knowledge of evolution and structure of the polarization electric field which drives instabilities.

In simplified form, the total polarization field caused by a meteor trail can be divided into two parts: (1) the electric field which is developed during the trail ambipolar diffusion and (2) the electric field in the trail and the surrounding ionosphere which is generated due to the presence of the external DC electric field associated with the equatorial or high-latitude E-region electrojets.

For the ambipolar diffusion electric field (1), we have developed a 2-D analytical theory and performed numerical computations of dynamics of electrons and ions with strongly different degrees of magnetization, assuming a finite angle between the meteor trail axis and the geomagnetic field $\vec{B}$, and taking into account the background ionospheric plasma. The low density ionospheric plasma closes particle currents originating in the trail and affects significantly the trail diffusion dynamics and the ambipolar electric fields. This study provides us with a quantitative estimate of the plasma density and electric field spatial distribution and dynamics.

For the equatorial and high-latitude electrojets, when a sufficiently strong DC electric field perpendicular to $\vec{B}$ occurs in the E region, assuming a highly conducting plasma trail and using some other simplifying assumptions, we have calculated the 3-D spatial distribution of the polarization electric field around the trail (2). This electric field may reach significant values (tens mV/m and more) and may excite instabilities that cause non-specular radar echoes. This may explain non-specular echoes which persist for a long time after the meteoroid it gone. However, for sufficiently big meteoroids when the linear plasma density in the trail exceeds $10^{15}$–$10^{16}\mathrm{m}^{-1}$, further increase in the meteor size results in saturation of the polarization electric field.

Combining our theory with radar observations of specular and non-specular echoes may yield useful information about meteor trails and the surrounding atmosphere.