Dissociative Attachment as a Possible Cause of Early VLF Perturbations

Robert A. Marshall, Umran S. Inan
STAR Laboratory, Stanford University, Stanford, CA

Early VLF events are lightning-induced perturbations to subionospheric VLF transmitter signals, so named because they occur immediately following the causative lightning discharge. The physical mechanism that initiates these events has been controversial since their discovery two decades ago. Primarily these events have been attributed to heating from the post-discharge quasi-static electric field (QE field) above the thunderstorm. Other theories involve the electromagnetic pulse (EMP) from the lightning discharge causing heating and ionization in the ionosphere; quiescent or sustained heating from the thundercloud charge, being perturbed by large lightning discharges; or scattering of the VLF signal from the sprite body. Scattering from the sprite body was suggested due to associations with sprites; however, the association is not one-to-one. Recent results have shown a correspondence between Early VLF events and sferic bursts, which are bursts of sferic-like impulses, shown to be due to in-cloud lightning activity. In this paper, we propose a new mechanism, involving electron density depletions due to dissociative attachment to molecular oxygen. We argue that EMP radiation from in-cloud lightning activity may cause enough of an electron density depletion, through cumulative effects of many (up to 100 or more) impulses, to explain many Early VLF events. Ionization due to the EMP does not have much effect, since it occurs above the VLF reflection height, and requires field values higher than observed. We show that attachment alone can cause VLF perturbations through Finite-Difference Frequency-Domain (FDFD) simulations of the subionospheric VLF signal propagation. Results of an EMP model of VLF radiation from lightning discharges confirm that in-cloud discharges can cause enough attachment to yield measurable signal perturbations. Together, these two models show that electron density depletions due to dissociative attachment may be a cause of many Early VLF events.