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Mesospheric electron detachment and LORE recovery times

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We present new results concerning the recovery times ($>$ 10 minutes) of *LOng Recovery Early VLF events* (LORE) in the upper mesosphere connected to electromagnetic pulses (EMP) of large ($>$ 250 kA km) charge moment change (CMC) $\pm$ CG (cloud to ground) lightning capable of producing elves or elve-sprite pairs (in the case of +CG parent lightning) [1], [2]. We have modeled two possible scenarios considering first the relaxation of slightly perturbed ambient electron densities ($n_e^0 + \Delta n_e$) without an impulsive ionization source and another scenario where the ambient electron density is considerably enhanced due to an impulsive ionization source (the lightning EMP).

The full non-equilibrium kinetic and 2D EMP modelling of the perturbed mesosphere in the 76 km - 92 km range during LORE occurring conditions indicates that the electron density relaxation time (defined as the time the perturbed electron density, Δn_e, takes to decay a factor 1/e of the way to the ambient electron density (n_e^0)) is critically controlled at each altitude by the relative importance of associative detachment (of O^- by, respectively, O and CO and of O_2^- by O) with respect to electron loss mechanisms (mainly 3-body, 2-body attachment and electron-ion recombination at the highest altitudes).

We found that the maximum electron density relaxation time ($>$ 15000 s) occur between 80 km and 82 km while it decreases with increasing altitudes to 12000 s (at 85 km) and about 2000 s (at 92 km). However, LORES are presumably due to VLF scattering from electron density enhancements caused by lightning-induced EMPs in the uppermost D region ionosphere (85 - 92 km). Thus the observed VLF signal recoveries (LORE recovery times) should associate with the relaxation of the maximum enhanced electron densities produced by elves between 85 km and 92 km [3].

Finally, our results for the lowest altitudes considered (76 km and 77 km) are in good agreement with the recovery times (between 20 s and 120 s) of the typical early VLF events associated to sprites [4], [5].

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