D region Ionosphere sudden perturbations associated with lightning and TLEs

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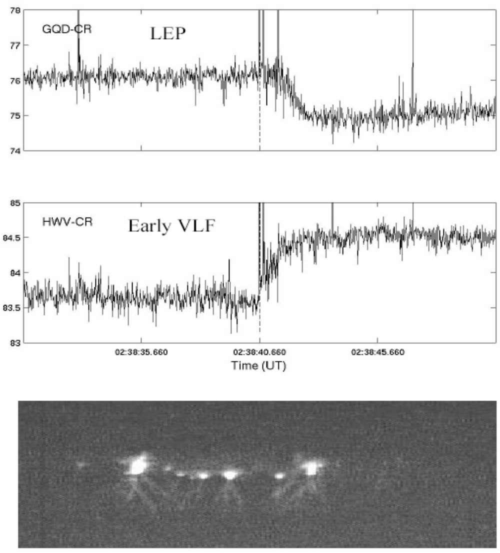
Traditionally, the ionosphere is defined as the part of the upper atmosphere where the number densities of electrons and ions are large enough to affect the propagation of electromagnetic (EM) waves. It extends form about 50 km up to a loosely defined upper boundary, which for most purposes may not exceed 500 km. The key physical ionospheric parameter is the electron density, while the symbols D, E, F1 and F2 are used to label the main ionospheric layers or regions. The ionosphere is a highly complex and anisotropic medium which undergoes a great deal of regular and irregular variability characterized by a wide range of temporal and spatial scales. The variability, which is imposed through energy coupling from sources below, above and within, is manifested through a wide range of ionospheric phenomena that have been researched intensively over the years. Tropospheric lightning discharges is a source of electrostatic and EM energy which can couple to the upper atmosphere and ionosphere, particularly the D region that is confined in altitudes between 50 and 90 km, causing abrupt conductivity perturbations which can affect very low frequency (VLF) signal perturbations. The topic of this talk relates to the last sentence.

Brief description

This is a general presentation dealing with irregular phenomena in the ionospheric D region caused by the effects of thunderstorm lightning. They are detected through sudden perturbations in VLF electromagnetic wave transmissions propagating in the so called *earth-ionosphere waveguide*. First, the basic properties of the medium will be outlined, placing the emphasis on electrical conductivity and the mechanisms by which it can be perturbed directly or indirectly by energy released from lightning discharges. By indirect perturbations we refer here to EM *whistler waves*, which originate in lightning-induced *atmospherics* peaking in the lower VLF range. They may penetrate into the upper ionosphere and then propagate along closed magnetic field lines in the magnetosphere. There, the whistler waves interact with radiation belt (Van Allen) energetic electrons which may be forced into the loss cone and thus precipitate into the lower ionosphere causing enhanced electron density perturbations. This *lightning-induced electron precipitation* (LEP) phenomenon, its basic mechanism along with the observed VLF perturbation signature and properties will be introduced here and discussed in brief. The emphasis of the talk, however, is placed on the direct lightning effects in the D region ionosphere, a topic on which members of our *EuroSprite* community have done research the last several years. The physical processes which impact in the upper atmosphere, through lightning-generated quasi-electrostatic fields and strong EM impulses, to initiate sudden perturbations in conductivity along with the concurrent production of *transient luminous events* (TLEs), mostly *sprites* and *elves*, as well as the manifestations observed in the sub-ionospheric VLF transmissions, known as *early VLF events*, will be presented and discussed in as much detail as the time permits.



Sprite at 02:38:40.660 UT

An example of an early VLF event occurring above a storm, a LEP event seen about 400 km north of the storm, and a concurrent sprite shown also in the lower panel. All three phenomena are energized by a strong positive cloud to ground (+CG) lightning stroke of 161kA current intensity.