Geophysical Research Abstracts
Vol. 17, EGU2015-11190-1, 2015
EGU General Assembly 2015

Study of the early signal perturbations due to GJ and Elves using the LWPC code

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Early events are a Very Low Frequencies (VLF) signal perturbations recorded during a lightning activity. The properties of these signal perturbations and their association to the lightning peak current and/or Transient Luminous Events (TLEs) were widely studied. In a recently analysis a new early signal perturbations whose recovery time persists for several minutes were discovered. The underlying cause of these events is still unclear. In a recently published work, these events were attributed to the lightning peak current and the type of associated TLE. In others, and newly published papers, analyzes were done where all kind of early events were considered. Statistical results showed that the occurrence of long recovery events is independent of the lightning current amplitude and/or TLEs type. To understand which is the main cause of these events, we analyzed two types of early signal perturbations: One was a typical event ($\sim$200s time duration) in association with a Gigantic Jet and the second was a long recovery event in association with an elve recorded on December 12 2009 during the EuroSprite campaign. In addition to the VLF signal analysis, we used the Long Wave Propagation Capability (LWPC) code to simulate the unperturbed and perturbed signal parameters (amplitude and phase), to determine the signal modes attenuation coefficient and then to infer the electron density increases in the disturbed region. The results showed that the reference height was reduced from its ambient value (87km) to 66.4 km in the case of the GJ and 74.3 km for the elve. These reference heights decreases affected the propagating signal at the disturbed region by increasing the modes attenuation coefficient. Effectively, the number of modes was reduced from 28 at ambient condition to 9 modes (in the case of GJ) and 17 (in the case of elve). This high attenuation of modes leads to the appearance of null signal perturbations positions due to the interferences. Between two null positions the signal perturbation was negative (or decreasing) and sometimes positive (or increasing). It was also observed from the LWPC code results that the perturbation amplitude was maximum when the perturbed and unperturbed signals were in phase. Thus the main reason of these observations is the modal structure of the signal at the disturbed region and the receiver location. The electron density increases reached 104 cm-3 at 85 km independently on TLE kind. By the use of the signal perturbation parameters due to the long recovery event and the LWPC code, a recovery time profile of the electron density at each height below 87 km is obtained. The first order exponential decay fit gives different recovery constants depending on the height. This is in good agreement with the atmospheric model where the loss terms rates vary with altitude.