Subionospheric VLF Measurements of Lightning-induced Ionospheric Disturbances

Inan Umran[1]

[1] STAR Lab., Dept. of Electrical Engineering, Stanford Univ.

Amplitude and phase changes of subionospherically propagating very low frequency (VLF) signals provided the first evidence of lightning-induced disturbances of the lower ionosphere, well before the observations of the luminous phenomena now known as sprites, elves, and gigantic jets. Typical signatures of lightning-related effects include secondary ionization enhancements due to the precipitation of energetic radiation belt electrons by lightning-generated whistler waves (known as LEP events) and the so-called Early/fast VLF events that are due to direct modification of the overlying ionosphere by thunderstorm generated fields. The former (LEP events) phenomena is now known to constitute an important loss mechanism for trapped radiation in the inner belt and slot regions, and extensive world-wide measurements are currently underway to quantify the relative role of lightning-generated waves in comparison with waves from other sources. The physical mechanism of the latter type of events (Early/fast events) is still under debate, as it is not known whether they are produced by electromagnetic impulses generated during lightning discharges, or by the quasi-static fields that lead to sprites. There is strong evidence that these type of disturbances are selectively produced by lightning events that involve clusters of intra-cloud flashes, in addition to one or more cloud-to-ground discharges. Early/fast events are sometimes observed in connection with sprites, but other times not, and their association with other optical phenomena, such as elves is not well known. In addition to LEP events and Early/fast VLF events observed with narrowband VLF measurements, VLF data from key sites around the world (especially from Palmer Station, Antarctica) has also been instrumental in detection of lightning discharges in association with Terrestrial Gamma-ray Flashes (TGFs). In this paper, we will present a review of VLF observations of lightning-ionosphere interaction phenomena.