Early VLF events.
A lower ionosphere VLF propagation signature coincident with Sprites

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Abstract

A Stanford narrow-band VLF receiver, which is now a component of the AWESOME network (http://nova.stanford.edu/~vlf/IHY_Test/pmwiki/pmwiki.php), has been in operation since 2003 in Crete, Greece (35.31^0 N; 25.08^0 E) in order to support *EuroSprite* campaigns in southwest Europe. It monitors several transmitters, some of them chosen in order to provide VLF links that traverse subionospheric regions in the proximity of areas viewed for transient luminous event detection by *EuroSprite* cameras and lightning detection systems (http://www.electricstorms.net/wiki/EUROSPRITE). The Crete VLF station provided the opportunity to study tropospheric lightning effects (http://cal-crete.physics.uoc.gr/VLF-sprites/VLFmain.html) impacted on the D region of the ionosphere, particularly those associated with the so called *early VLF events*.

The early VLF events are characterized by abrupt perturbations in the VLF signal, occurring within less than 20 ms of a lightning atmospheric. Their sharp onset is marked by a gradual recovery lasting from several seconds to several tens of seconds. This VLF phenomenon has been studied extensively in an effort to understand the physical mechanism behind the early event occurrence and its relation to the transient luminous events (TLEs). The question regarding the correlation between sprites and early VLF events has been a key topic of study of the last fifteen years and a matter of some controversy.

This presentation summarizes recent Crete findings on the nature of the early VLF phenomenon. After a brief review of the topic, some unquestionable evidence is presented, showing that sprites are accompanied by early type perturbations in a one-to-one correspondence, in support of what has been hinted in early Crete studies on the same topic. This implies that the sprite generation mechanism is also capable of producing nearly always electron density increases in the upper D region of the ionosphere which lead to conductivity changes responsible for VLF scattering and thus detection of early VLF events. While it is shown that every visible sprite is accompanied by an early event, the reciprocal association of early VLF events observed in conjunction with sprites appears not to be clear and requires clarification by using more sensitive optical measurements and carefully conducted experiments. We also show that recovery simulations, obtained by using the simplified Gluhkov-Pasko-Inan model, are useful in gaining physical insight on the ionization loss mechanisms and obtain relative estimates of electron density production levels. Finally the consequences of these findings will be emphasized and hints for further research and progress beyond our present knowledge will be mentioned and discussed.

In brief, the results here provide a definitive answer to the long standing question: Are sprites accompanied by ionization production in the D region? The nearly one-to-one correspondence of visible sprites to typical early VLF events implies clearly that sprites are indeed accompanied with electron density production in the D-region. However this sprite-related ionization production still remains to be quantified and modeled. Also the present results show also the need to model and understand better the scattering of VLF signals from sprite-causative lightning produced sub-ionospheric electron density perturbations.

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