Characteristics of lightning associated transient perturbations in low latitude VLF path

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Abstract

Lightning can perturb the sub-ionospheric VLF propagation directly or indirectly. Direct perturbations in the sub-ionospheric VLF signals occur within 20 ms of the associated lightning discharges while the indirect perturbations occur through the lighting generated whistler mode waves in the magnetosphere. These whistler mode waves undergo cyclotron resonance with the trapped electrons in the magnetosphere. The electrons which are pitch angle scattered into the loss cone, precipitate into the ionosphere producing secondary ionization in the lower ionosphere. This process produce indirect VLF perturbations known as lightning induced electron precipitation (LEP) events. We analyse such events for the VTX-Kolkata and NWC-Kolkata path. We observe several events. Some of them have positive shifts while others have negative shifts. We fit the events with FRED (Fast Rise Exponential Decay) function to characterize the onset and recovery time. We explain positive and negative VLF amplitude deviation due to lightning events using the most well-known Long Wavelength Propagation Capability (LWPC) code.

1 Introduction

Lightning discharges radiate a broad spectrum of electromagnetic energy from few Hz to tens of MHz with maximum spectral energy concentrated in the ELF/VLF band. ELF/VLF waves propagate along the earth-ionosphere waveguide. In the near-field region of the lightning flash, the wave energy can be thought of as a ray which reflects back and forth between the earth and the ionosphere. At each reflection, a portion of the wave energy is lost into the magnetosphere as a whistler-mode wave and propagates along the magnetic field line. Upon entering the magnetosphere, the wave propagates out to the equatorial region and interacts with the radiation belt electrons, thereby changing the pitch angle of some of the electrons reducing it below the loss cone, causing the electrons to impact the ionosphere and precipitate. This whole process takes almost 1 sec time called the onset delay. The physical mechanism of LEP event is depicted in the Figure 1. LEP events have been extensively studied using ELF/VLF waves as the main probe mostly by Stanford University [Inan et al., 1995 and references therein] and also by many others [Dowden, 1996; Rodger, 2003; Hobara et al., 2006].

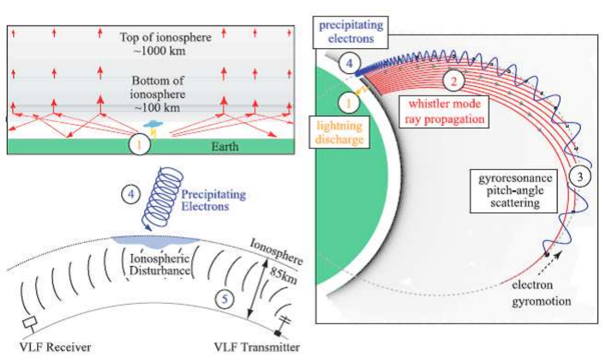

Figure 1: Physical mechanism of lightning induced electron precipitation following Lauben et al., 2001.

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2 Data analysis

As for example, we present the analysis of the VLF data along VTX-Kolkata path for the year of 2007. 59 such events were observed throughout the year, the maximum number of events being observed in February. These 59 events include both positive and negative shifts in amplitude as shown below in tabular form.

Sl. No.	Month	No. of events	Number of positive events	Number of negative events
1	January	7	5	2
2	February	12	9	3
3	March	5	2	3
4	April	8	4	4
5	May	5	2	3
6	June	2	0	2
7	July	3	2	1
8	August	1	0	1
9	September	2	1	1
10	October	8	3	5
11	November	5	1	4
12	December	1	1	0

Figure 2: Statistics of LEP events for the year of 2007.

In Figure 3, we show the typical positive amplitude perturbations associated with lightning events occurred on 6th February, 2007 (left) and 14th January, 2007 (right) respectively. We find an interesting group of consecutive events which occur within the time frame of 1 hour on 9th May, 2007 with negative amplitude deviation and are presented in Figure 4. To characterize the onset and recovery time more precisely, we use the Fast Rise and Exponential Decay (FRED) type function. Examples of such fittings are given in the Figure 5.

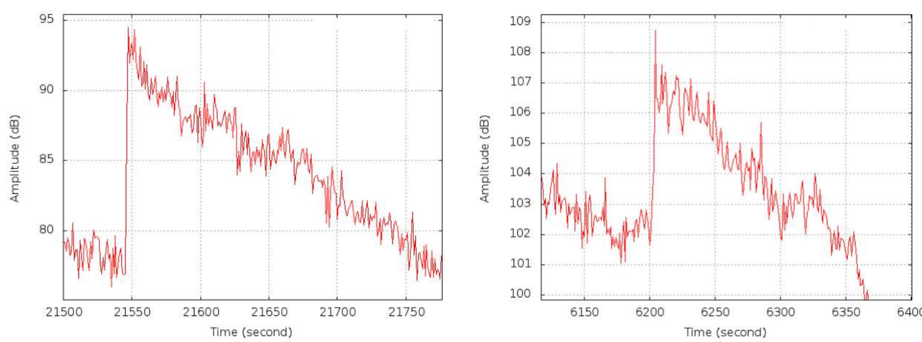

Figure 3: Example of events with positive amplitude shift due to lightning on 6th February, 2007 (left) and 14th January, 2007 (right).

3 Conclusions

We detected lightning associated transient perturbations in low latitude VLF paths. We find both negative and positive amplitude deviations in the same path and also in same day. We are in process to explain the observed behaviour associated with such events using the LWPC code.

4 Acknowledgements

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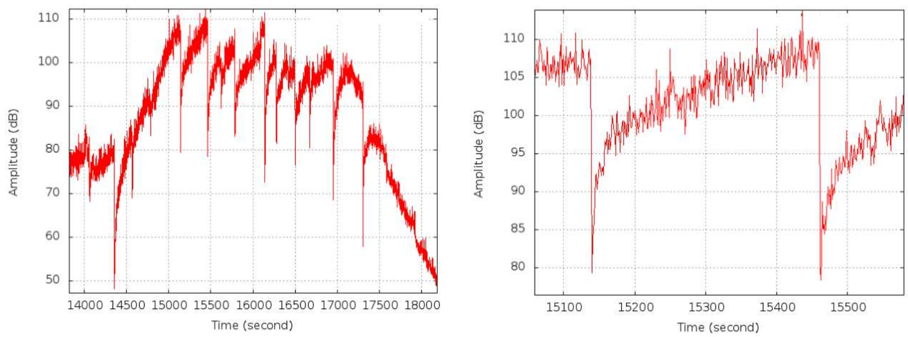

Figure 4: An interesting group of LEP events with negative amplitude deviation on 9th May, 2007 (left). Zoomed portion of an event (right) from the group.

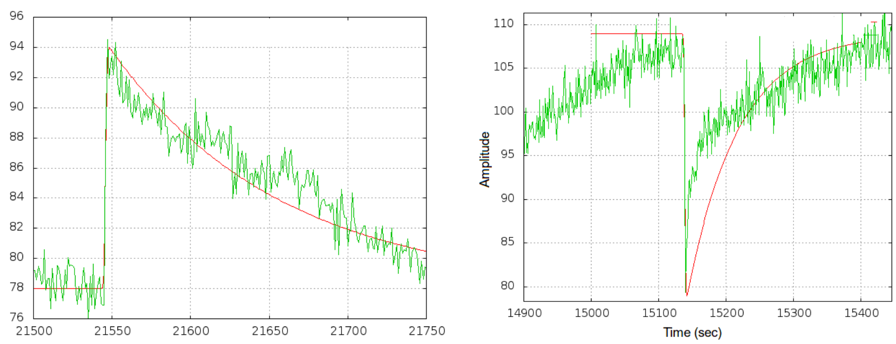

Figure 5: Examples of fitting observed signals of positive (left) and negative (right) deviation with Fast Rise and Exponential Decay (FRED) type curves (red) which are due to the quick response of the ionosphere to the secondary ionization by the precipitating electrons and subsequent slow decay due to the recombination of the ions.

5 References

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