Ionospheric Effects of Lightning at Camp Blanding, Florida

Robert C. Moore[1]

[1]University of Florida, 319 Benton Hall, P.O. Box 116200, Gainesville, Florida, USA, moore@ece.ufl.edu.

Abstract

The International Center for Lightning Research and Testing (ICLRT) in Camp Blanding, Florida is world-renowned for high-resolution measurements of lightning. In this paper, we describe the latest enhancements to the ICLRT facility. Very low frequency (VLF) remote sensing is employed to monitor the ionospheric effects of lightning observed at the ICLRT. VLF signals are sensitive to electron density and temperature changes in the lower ionosphere, such as those produced by the direct coupling of lightning energy (e.g., the sprite halo or possibly elves). We present initial results from this new monitoring system.

1. Introduction

The direct coupling of lightning energy to the overlying ionosphere is most prominently evidenced by the fantastic luminous events known as sprites [1], elves [2, 3], and related phenomena [4, 5]. A number of these optical phenomena have been experimentally correlated in time with the scattering of subionospherically-propagating VLF waves [6,7], whose propagation characteristics depend upon the electron density and temperature of the *D*-region ionosphere [8]. Ionospheric disturbances related to lightning affect wave propagation from the very low frequency (VLF, 3-30 kHz) band through to the high frequency (HF, 3-30 MHz) band [9], at times creating >6 dB signal perturbations in signal amplitude [10]. Due to the difficulty in experimentally separating the effects of the various optical phenomena, there is some controversy regarding the physical mechanism responsible for the observations of VLF scattering. The causative lightning waveform has also not yet been completely characterized, primarily due to the difficulty in collecting the vast data sets required to do so, although it should be noted that some progress has been made in the ELF/VLF band [11]. However, simple lightning waveform statistics (e.g., peak current) do not appear to be good indicators for the optical events: not every strong, positive polarity cloud-to-ground lightning discharge produces a sprite, for example. The current study aims to experimentally determine the phenomenological properties of the causative lightning waveform that successfully produces VLF scattering events.

In this paper, we describe a new effort at the International Center for Lightning Research and Testing (ICLRT) in Camp Blanding, Florida to perform high-resolution, wideband (30 Hz-5 MHz) observations of the lightning waveforms responsible for ionospheric effects, as determined by VLF remote sensing. We describe herein the method employed for event detection, and we discuss the current state of the experimental preparations.

2. The ICLRT

The ICLRT at Camp Blanding, Florida, is a 1 km × 1 km research site at the Camp Blanding Army National Guard Base. Distributed over the ICLRT is a ~20 station electric and magnetic field measuring system to enable the remote characterization of both triggered and close naturally-occurring lightning [12]. At a distance of 100 km, a single electric field receiver can measure the polarity of the lightning stroke and other lightning processes, the time-evolution of the current waveform (including the peak current by modeling of the fields), the total charge moment change, and the radiation-field spectrum of the lightning return stroke (which may be modified by propagating over a finitely conducting Earth) [13].

Figure 1 shows an example of a typical wideband cloud-to-ground (CG) lightning waveform with preliminary breakdown pulses. Similar resolution waveforms for intracloud (IC) and narrow bipolar (NBP) are available. This record was acquired on the roof of Benton Hall at the University of Florida, some 50 km from the causative flash. The typical cloud-to-ground stroke signature is distinctly different from that of intracloud lightning, and narrow bipolar pulses are altogether different from the both CG and IC lightning. As may be surmised from Figure 1, wideband measurements of the lightning radiation in the radiation zone can aide in the determination of lightning characteristics that directly couple to the ionosphere, as can field measurements at very close range. High energy phenomena (not shown) also accompany the generation of lightning: at the ICLRT, well-documented X-ray bursts have been observed on the ground coincidentally with the electromagnetic radiation produced by dart leaders from rocket-triggered lightning and the stepped leaders from natural lightning [14, 15].

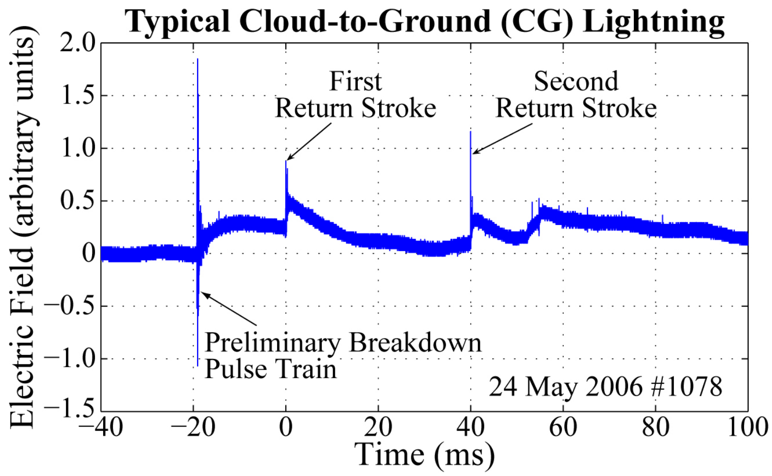

Figure 1: A typical 140 millisecond Cloud-to-Ground (CG) lightning waveform observed on the roof of Benton Hall at the University of Florida (with preliminary breakdown pulses).

3. Very Low Frequency Remote Sensing

VLF Navy transmitters operate in the ~20-30 kHz portion of the VLF band for communication with submarines. These 200 Hz bandwidth signals may propagate to large distances with low attenuation as they are guided within the Earth-ionosphere waveguide [16], which is formed by the conducting Earth on the inner shell and the conducting lower ionosphere (at 60-100 km altitude) at the outer shell. The received amplitude and phase of the narrowband VLF signal depend sensitively upon the ionospheric reflection height of the VLF signal which varies about ~80–90 km altitude [8]. The direct coupling of lightning energy to this altitude range of the overlying ionosphere may thus affect the received amplitude and phase of subionospherically propagating VLF signals for a time period consisting of the sum of the event duration (<20 milliseconds) [17, 18] and the timescale for ionospheric

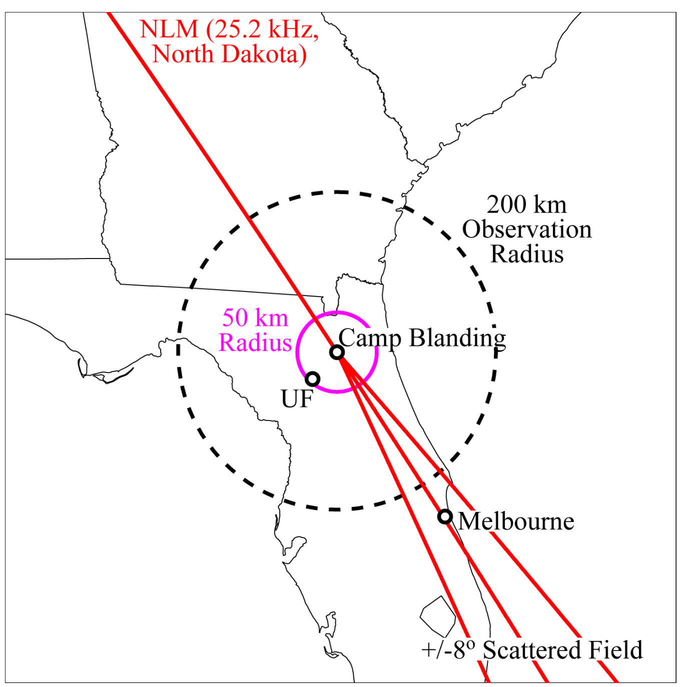

Figure 2: Geometry of the Camp Blanding VLF scattering experiment.

relaxation (~10–100 seconds) [19]. Extensive measurements of VLF perturbations related to direct ionospheric coupling have been presented over the years [17, 20-23], documenting the fact that VLF remote sensing is an excellent means for detecting and quantifying such events.

For the current application, a VLF receiver has been installed in Melbourne, Florida to track the amplitude and phase of the NLM transmission (25.2 kHz, North Dakota) for the purpose of detecting VLF scattering by ionospheric disturbances near Camp Blanding, Florida. The experiment geometry is shown in Figure 2. The size of the disturbance shown in Figure 2 is 100 km in diameter, on the same order of magnitude as that experimentally determined for early/fast VLF events [22].

4. Initial Results

Figure 3 shows a selection of data from the Melbourne VLF site on its initial date of installation, 13 February 2008. The left portion of the figure shows a 60-second duration spectrogram covering the frequency range 0-50 kHz. An analog 9 kHz high-pass filter is employed to reduce interference by power line hum (60 Hz and its harmonics). The many intense vertical pulses are lightning-produced radio atmospherics. The NLM transmission is clearly seen in the spectrogram as a 200 Hz wide horizontal line centered at 25.2 kHz. The amplitude and phase of the NLM transmitter for a period of 36 minutes is shown in the right two panels of Figure 3. Three examples of possible VLF scattering events are highlighted on the figure, although these events have not yet been correlated in time with lightning flashes.

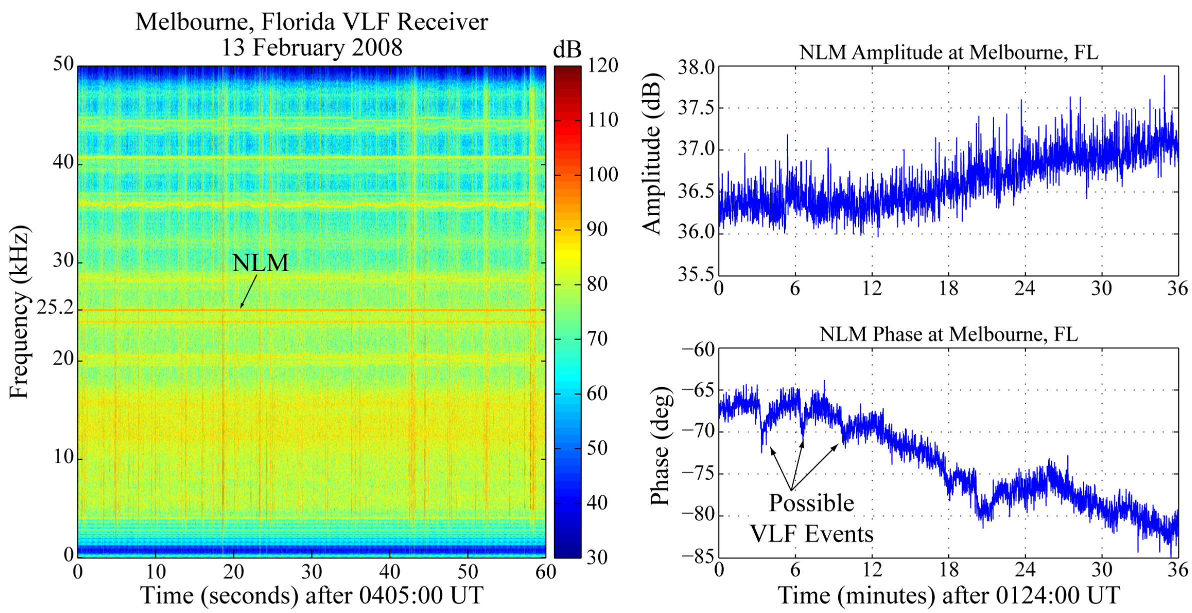

Figure 3: Initial data from the VLF receiver at Melbourne, Florida.

5. Conclusion

VLF remote sensing in an important tool that is now available to analyze the ionospheric effects of lightning observed at the ICLRT in Camp Blanding, Florida. In conjunction with the high-resolution observations of the causative lightning waveforms at the ICLRT, the monitoring system may help address several unanswered questions regarding the causative physics responsible for a variety of VLF events, including early/fast events, early/slow events, and long-recovery events.

6. References

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