LIGHTNING OBSERVATIONS at UHF and VHF with WIND-PROFILER RADARS IN PUERTO RICO

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ABSTRACT

During September and October 1998, a thunderstorm experiment was carried out at NAIC in Puerto Rico, an island located in the tropics. An experimental set up was deployed on the site including UHF and VHF wind-profiler radars, an electrical field mill and a disdrometer while radiosoundings are launched twice a day in a separate place of the island, and a NexRad radar scans all over the island. With this set of data, different approaches have been considered.

In case of lightning flashes, radar receivers detect the backscattering by the plasma channel and the direct radiation of the lightning channels. An approach was to compare the time variation of the VHF signal with the atmospheric electrical field variation in order to validate the origin of the VHF observations. At UHF, as it was expected the magnitude was weaker, but the backscattering by the plasma channel was present. In this paper, the characteristics of the lightning radiation and plasma channel will be determined and analysed in the context of the Thunderstorm dynamics and precipitation.

INTRODUCTION

At the National Astronomy and Ionospheric Center (NAIC) in Arecibo, Puerto Rico, during September/October 1998, a campaign was carried out to observe tropical thunderstorms. The observations of several cloud formations were carried out with an electrical field mill, NAIC dual-wavelength (UHF and VHF) and NEXRAD radars, disdrometer, and rain gauge. The data so collected will be used to describe tropical thunderstorms. For the first time in Puerto Rico the electrical activity was observed continuously during nearly one month.

Chilson et al. (1993) and Keener at al.(1993) carried out similar experiment at Arecibo but without electrical field mill and with a different timing for the UHF and VHF radars. Röttger et al.(1995) worked at VHF in an interferometric mode. The aim of this paper is to give results obtained on lightning flashes during thunderstorm experiment.

ELECTRICAL FIELD DATA

Observations were conducted with an inverted field mill, provided by Väisälä company, and installed close to a building. As the fair-weather value commonly indicated by the sensor during the campaign is close to -120V/m, it can be suspected that the proximity of the building have a moderate shielding effect on the calibration of the sensor.

The electrical field mill measurements provided information on the build-up of the electrical activity over a range of about10 km; its maximum range being around 30km for a thundercloud electrically active. The resolution of the sensor is 39V/m for a total range of +/- 30kV/m. The measurement is sampled at a 10Hz rate providing a time response to an electrical field step shorter than 200ms. This time response is fast enough to make possible the identification of the field variations produced by lightning flash. The data acquisition threshold was $\pm$ 300 V/m for this experiment.

Electrical field mill data were collected on 30 days during the experiment, except during the passage of hurricane Georges. During 20 days, the thunderstorm occurred mainly from 13-

14h until 17-19h either over the observatory or not too far from it. The activity lasted more than 2 hours with a maximum value of 8 hours. For four situations, significant slow variations of the electrical field and fast variations produced by lightning flashes were observed during nightime, the overall duration of a detected storm event depending on the distance from the instrument.

However, only on seven of these days rainfall amounts were greater than 10mm; that means that on the other days the maturity and decreasing-activity of the thundercloud did not occur over the observatory.

SIGNATURES OF LIGHTNING ON UHF (430MHz) AND VHF (46.7 MHz) SIGNALS

During this experiment the measurements were carried out simultaneously at UHF(430MHz) and VHF (46.7MHz) with a 2 s pulse; the InterPulse Period being 1ms. In clear air or precipitation conditions, the first significant observation is only at 5.6km altitude due to the radar system and then above the melting layer typically located around 4-4.5km. In case of lightning flashes, the signal received is a mixture of radiation and backscattering by electrons and/or temperature gradients, superimposed on the regular atmospheric signal.

In order to compare the radar measurements to the electrical field data, the radar data are averaged over 100 ms for each gate. On figure 1, time series of VHF and UHF backscattered amplitude are plotted simultaneously with electrical field variations. At UHF, all the lightning flashes are not detected, perhaps because of the attenuation of the receiving system. VHF signals and electrostatic field variations are post synchronized on that figure, despite synchronization difficulties due to field meter clock drift, (several seconds in that case). If the amplitude of simultaneous spikes at 8.7km and in the calibration gate are compared, we note a difference due to the fact that the lightning radiations are pulsed.

On VHF radar plots (backscattered amplitude versus time and height) "vertical" intense lines, at all altitudes including the calibration gates, are observed (figure not shown). Each event lasted around 20-60ms. On the UHF plots such features are not observed due to the strength of the signal itself. It is clear from the signature in the calibration gates that the spikes cannot be related to the radar reflectivity or saturation. The "vertical" lines correspond to a series of radiation pulse distributed in time and in space. The time interval between two events goes from 20ms up to several hundred ms, which is typical of time interval between successive recoil streamer processes (K change) and also typical of subsequent strokes. The same behavior was reported in the review by Williams et al. (1990).Most of the lightning-radiation events lasting 20-60ms, this duration of VHF emission event exceeds the expected duration of only a recoil streamer process and may also imply subsequent strokes.

On some VHF plots, superimposed to the signal due to the lightning radiation, permanent signal was observed during hundred ms and located in an altitude range close to 1km around 7km. This signal is due to the signal backscattered by the ionised channel; phenomena not observed when the transmitter is off. In this altitude range, the temperature fluctuates between –10.5°C and –17°C, values obtained from the radio sounding data at 8:00 and 20:00 AST in San Juan (P.R.). The width of the enhanced signal zone is explained by the fact that lightning channels are not distributed uniformly with height in thunderstorms, but tend to occur most often in layers considerably smaller than the depth of the storm; they tend to occur in one or two layers. These temperature and altitude ranges are similar to what has been observed by previous investigators and correspond to the lower layer; the upper layer corresponds to temperatures lower than -18° C (see Mc Gorman and Rust, 1998). The origin of the backscattered signal is the backscattering by electrons or/and by temperature gradient between the channel and the surrounding atmosphere that modifies the refractive index. The interpretation of the duration is difficult as it is necessary to separate the channel evolution from the effect of the main-lobe beam diameter; at 7km the beam diameter being around 232m. Further detailed analyses are ongoing.

The radar only observes the backscattering by the ionised channel if the channel is located in the radar field of view (main or near-side lobes). In some events, they are not observed at all being too far from the radar. When the channel occurs in a side lobe the backscattered signal will be observed at a higher altitude than the actual one. The reflectivity may be used to separate the case of the channel occurring in a side lobe from the case of the channel in the main lobe at upper altitude (Keener, 1995a).

On Fig.2, at UHF the signal backscattered by the hydrometeors is relatively intense; a Fourier transform of this signal provides the vertical speed of the particles. At 11.9km a short period oscillation is superimposed on the larger variation due to hydrometeor motion. This oscillation is observed in the neighbour gates over a 1.5 km-height range and corresponds to a zone of enhanced signal at both frequencies related to backscattering on the ionised channel. This time period corresponds to a Doppler velocity close to the vertical air velocity. This phenomenon was reported by Zrnic et al. (1982) and Keener and Ulbrich (1995 b).

CONCLUSION

This paper describes some examples of the electrical activity observed with the electrical field mill; it was the first measurements in Arecibo, Puerto Rico.

Future works consists to associate with this data the VHF or/and UHF data (vertical velocity, type of hydrometeors) and the NEXRAD data to describe the thunderclouds and their environment. It might be possible to compare position in the cloud of ionized channel and VHF pulsed emission produced by the discharge. Such comparison can enlighten the process of formation and propagation of discharge.

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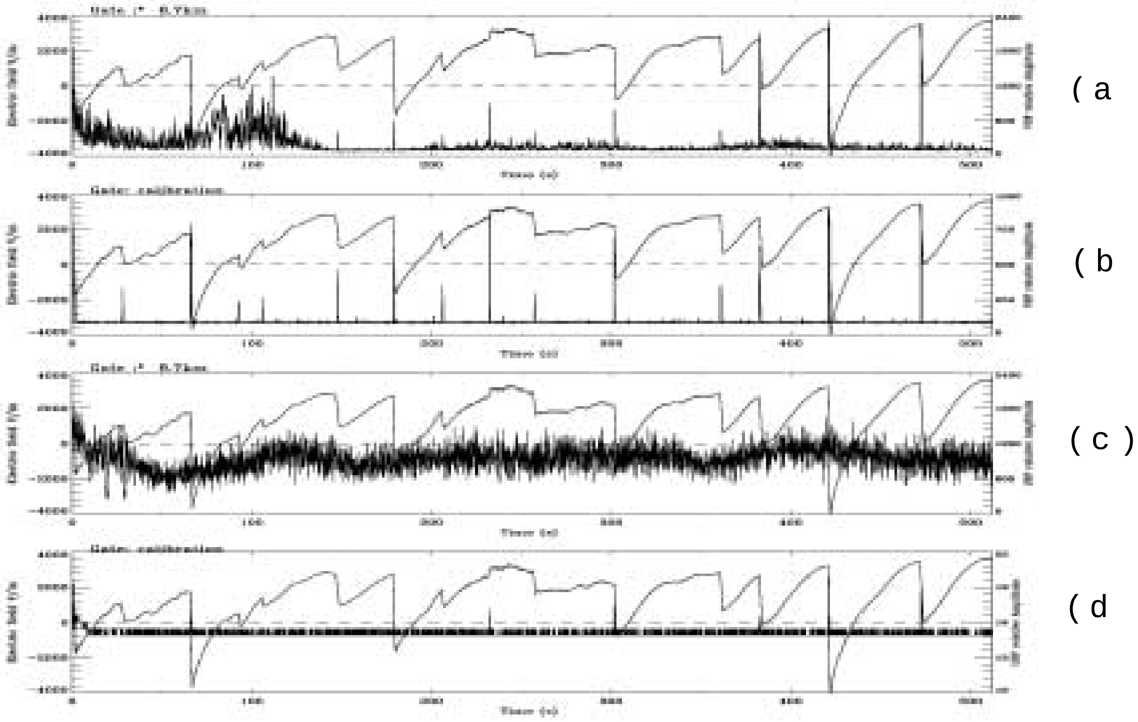

Figure 1: Arecibo - October 8, 1998 from 16:45:45.8 LT until 16:54:17 LT
Noisy signal:VHF (a,b) and UHF(c,d) time series of the backscattered signal averaged over 128 gate. Thin line: Electric field variation

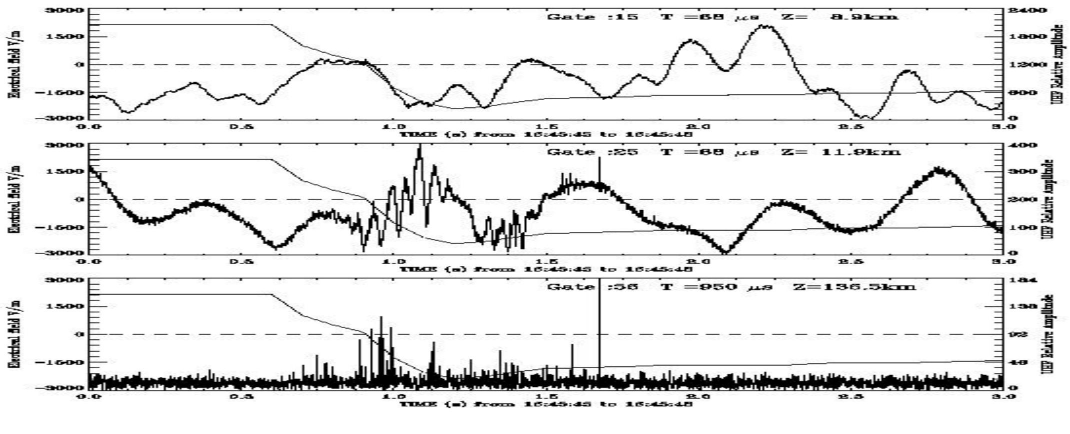

Figure 2: Electrical field variation as a function of time observed with a ground-based electrical-field meter on October 8, 1998; the transmitter is on. Superimposed is the VHF relative amplitude observed at the same time at 2 different altitudes and calibration gate. T: time delay between the pulse transmission and the sampling time; Z: altitude of the signal backscattered by the air turbulence.