Reception of Extremely Low-Frequency "Atmospherics" from Tropical Storms

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1 February 1967 and 13 March 1967

1. Introduction

In this note, examples are presented of "slow tail" extremely low-frequency (ELF) "atmospherics" generated by distant (~ 5000 km) lightning discharges in the areas of tropical storms (typhoon Rita and hurricane Blanca, August 1966). The vertical and horizontal electric fields components of the waveforms were measured at a single recording station employing a vertical antenna and an orthogonal set of earth probes. The detailed instrumentation has been presented elsewhere (Hughes, 1967a). Because of the transient nature of the waveforms, a comparison of the initial polarity of vertical antenna signature with the earth-probe signatures removes the omnidirectionality of the vertical antenna. The angle of arrival within a particular quadrant is then determined by the ratio of the peak amplitudes of the east-west and north-south earth-probe signatures. The distance to the source is then estimated from the rise time or duration of the first quarter-period of the waveform and known propagation constants of the earth-ionosphere waveguide (Wait, 1962).

Thunderstorms are frequently observed in the early and decaying stages of tropical storms and also around the periphery of the storm (Dunn, 1951). They are not usually observed in the areas of winds over 60 mph in immature and mature storms. The present technique of source location does not allow sufficient range resolution to determine if the waveforms emanated from the periphery or the regions of intense winds. However, the waveforms presented here were received during the mature stages of the storms.

The waveforms received from the storm areas were predominately generated by intracloud (IC) lightning discharges. The number of IC discharges from the storm areas exceeded the number of cloud-ground (CG) discharges by at least an order of magnitude. The number of IC discharges in convective or frontal type thunderstorms is usually only a factor of 2 or 3 greater than the number of CG discharges (Tepley, 1961). The receipt of an unusually large ratio of IC to CG waveforms emanating from an area may be indicative of the degree of vertical development of a storm.

2. Description of 'slow tail' waveforms

The signatures of atmospheric waveforms displayed on an oscilloscope usually consist of two portions, an

"oscillatory head" and a quasi-sinusoidal "slow tail" portion. The "oscillatory head" is composed of the very low-frequency components (3–30 kHz) which reach the receiving station prior to the extremely low-frequency components (0–3 kHz) which contribute to the "slow tail". However, depending upon the source distance and frequency response of the receiving equipment, the "slow tail" may not always be preceded by an oscillatory head.

The initial portion of the "slow tail" may either have positive or negative polarity. The "slow tails" of positive polarity are generated by the return stroke of a CG lightning discharge (Hepburn, 1957), and "slow tails" of negative polarity are almost always caused by IC lightning discharges which result from the transfer of positive charges from the top to the base of the cloud (Tepley, 1961). The term "positive polarity" is here taken to mean that the electric vector of the initial portion of the waveform is directed upward at the receiving antenna and "negative polarity" means that the electric vector of the initial portion of the waveform is directed downward.

At ELF, the change in phase upon reflection at the boundaries of the earth-ionosphere waveguide is small and the spectral components of the "slow tail" waveform move down the waveguide in an almost coherent fashion. The initial polarity of the waveform does not change during propagation through the waveguide. Because of the dispersive properties of the waveguide only the rise time, amplitude and duration of the pulse change as the distance to the source increases. Thus, the initial polarity of the waveform indicates whether the source was a CG or IC lightning discharge. The identification of positive polarity waveforms with CG discharges and negative polarity with IC discharges is not infallible. Perhaps 5% of the CG discharges and 20% of the IC discharges do not follow this rule. It has been shown elsewhere (Hughes, 1967b) that the radiated electric fields of CG and IC lightning discharges are comparable at extremely low frequencies and only the IC waveforms will be discussed here.

3. Measurements

During the month of August 1966, simultaneous recordings of the vertical and horizontal electric fields of "slow tail" waveforms were made in a remote area of the Hawaii Volcanoes National Park. Subsequent

analysis of the recorded data indicated two areas of intense spheric activity located at approximately 146E, 25N and 120W, 22N. An examination of synoptic meteorology data indicated that at the times of recording these were the approximate locations of two tropical storms, typhoon Rita and hurricane Blanca, respectively. Recordings had been made during the periods of local midnight (0005–0035 HST) and local noon (1205–1235 HST) on 3, 4 and 5 August 1966 such that the propagation paths from both disturbances were under either full nighttime or full daytime conditions. Typical examples of IC waveforms are shown in Fig. 1. Figs. 1a and 1c are examples of “slow tail” received from typhoon Rita during full day and nighttime conditions, respectively. Figs. 1b and 1d are examples of “slow tails” received from hurricane Blanca during full day and nighttime conditions, respectively. Figs. 1a–c are examples of waveforms classified by Liebermann (1956) as

Type I while Fig. 1d is a Type II waveform. It has been reported elsewhere (Hughes, 1967a) that the Type II and I waveforms are predominately easterly and westerly propagating waveforms, respectively, for nighttime conditions. The directional dependence does not exist under daytime conditions and the waveforms are predominately Type I. Figs. 1c and 1d are examples of the nighttime directional dependence. The directional dependence of the waveform characteristics may prove to be a further aid in locating storms areas. The differences in appearance between the earth-probe signatures and those of the vertical antenna in each case can be attributed mainly to the differences in frequency response of the three systems.

The approximate location of the waveforms with respect to the reported storm positions at 1200 GMT 5 August 1966 are shown in Fig. 2. The source locations were determined from the rise times of the vertical

FIG. 1. Example of intracloud (IC) ‘slow tail’ waveforms received from typhoon Rita (daytime, A; nighttime, C) and hurricane Blanca (daytime, B; nighttime, D). The first and third traces in each example are the vertical antenna signature of the same waveform and the second and fourth traces are of the E-W and N-S earth-probe signatures, respectively. In each case, the horizontal scale represents time increasing to the right and each major division corresponds to 2.5 msec in A and B, 1.5 msec in C, and 1.0 msec in D. The vertical scale is the output voltage of the tape recorder and corresponds to 1.0 volt per major division in each example.

Fig. 2. Approximate locations of the waveforms shown in Fig. 1 with respect to typhoon Rita and hurricane Blanca.

antenna signatures and the ratios of the peak amplitudes of the earth-probe signatures. Ideally, the source locations should have been shown on an azimuthal-equidistance map with the measurement site at the center. However, it would have been necessary to prepare such a map specifically for this purpose. The measurement site of the island of Hawaii was approximately 200 n mi east of Honolulu.

4. Conclusions

It has been demonstrated that ELF waveforms originating in areas of severe tropical storms can be located at a considerable distance from a single recording station. A fully automated system would be a valuable supplement to present methods of tropical storm location and intensity classification.

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