THUNDERSTORM COUPLING TO THE MAGNETOSPHERE AND ASSOCIATED IONOSPHERIC EFFECTS

Semiannual status report

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Introduction

This project deals with the coupling of electromagnetic energy released during a thunderstorm to the magnetosphere and the ionosphere. Both the effects of an individual lightning event as well as aggregate of all the lightning events during a thunderstorm are considered. Energy in the very low frequency (VLF) band can play a variety of roles in the magnetospheric and ionospheric physics: generation of plasmaspheric hiss believed to be responsible for the slot region in the radiation belts, generation of lower hybrid waves that can heat ions in the auroral and subauroral regions, precipitation of energetic electrons, ionospheric heating etc. While these phenomena have been identified, and characterized to some extent, the influence and role of thunderstorm energy on the magnetosphere and ionosphere at a global scale is not known.

Only recently, simultaneous high resolution (temporal and spatial) data sets from ground based lightning detectors and space and ground based VLF detectors have become available, and thus it has become possible to raise a question of the kind mentioned above and try to answer it quantitatively. END

Significant Achievement

The work on the correlation between individual lightning discharges in a thunderstorm as detected by the lightning network and the whistlers observed on the DE 1 satellite was continued during this six-month period. From the two periods (Dec-Jan 1986-87, and Nov 87) and fifteen cases that were identified suitable for this study, six (three from the first period and three from the second) were selected for detailed quantitative study. The principal criterion used was that there should be enough events over a few minutes period when the satellite essentially remained in the same parts of the magnetosphere to provide reliable statistics, but that the rate of events/min should be small enough to determine unique correlation between individual lightning discharges and whistlers. Figures 1a and 1b show, respectively, the area covered by the lightning detection network and the meridional projections of DE 1 orbits for the two periods (Jan 87 and Nov 87). Note that the DE 1 satellite covers two distinct parts of the inner magnetosphere (plasmasphere) in Jan and Nov 1987. The spectral signatures of whistlers observed in these regions are quite different and are shown in Figure 2. At lower altitude (Nov 87 period), discrete magnetospherically reflected whistlers are observed, whereas at higher altitude (Jan 87 period) whistlers follwed by diffuse hiss are observed.

The whistlers observed on the DE 1 were time-correlated with lightning discharges detected by the lighting network using the following known properties of nonducted propagation of VLF waves from the ground to the satellite [*Sonwalkar et al.*, 1984].

(1) If the source location is same (reasonable assumption since thunderstorm region extends over only a few hundred kilometers), then the time delays between the causative lightning discharges and the observed whistlers should vary continuously as a function of the satellite location.

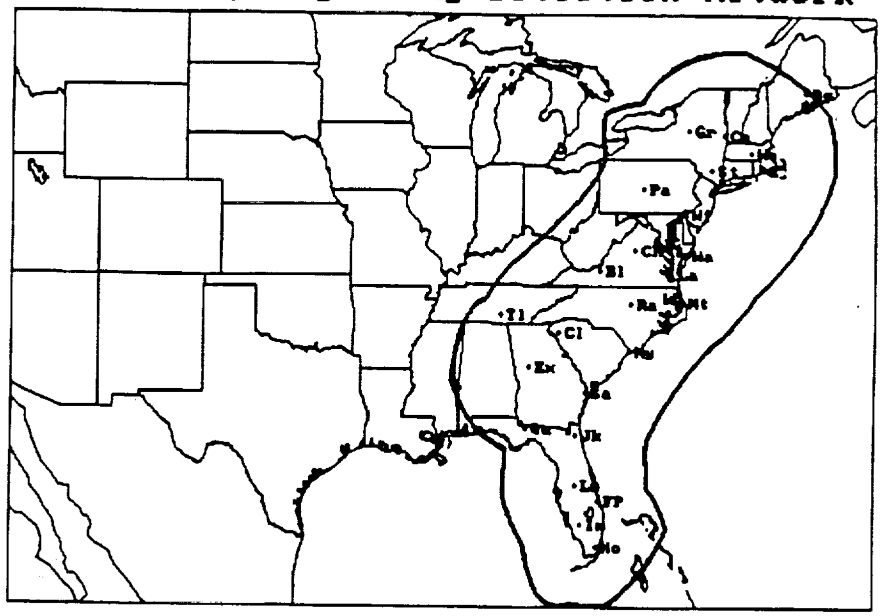
(2) Direct multiple path may cause a few hundred millisecond fluctuations in the measured time delays from one event to the next.

Figure 3a shows an example of measured time delays for 16 Jan 87 case. 2-D ray tracing simulations were carried out to confirm the measured time delays. Figure 3b shows the location of lightning discharges and the magnetic and ray tracing footprint of the DE 1 satellite when the measurements were performed. Figure 4 gives the summary of the correlations between the lighting discharges and the whistlers for the six cases. Note approximately 50-60% of the lighting discharges lead to detectable whistlers in the magnetosphere.

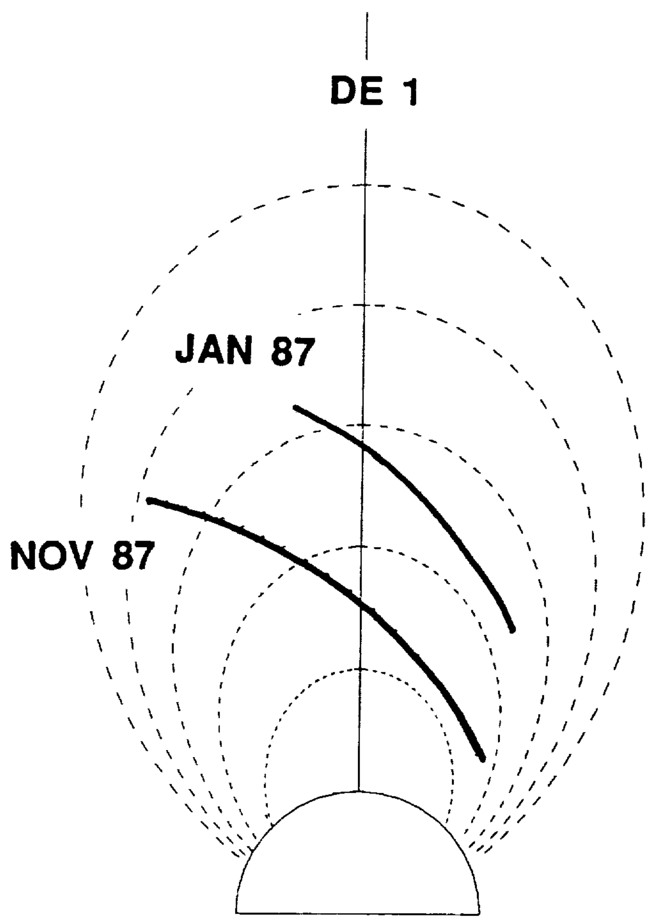
The next step is to correlate properties of lightning discharges to the properties of correlated whistlers. This would provide information (1) on when a lightning discharge contributes significant energy to the magnetosphere, and (2) spatial extent in the magnetosphere over which energy from individual discharges is detectable.

FIGURE 1

SUNY-Albany Lightning Detection Network



(a)



(b)

FIGURE 2

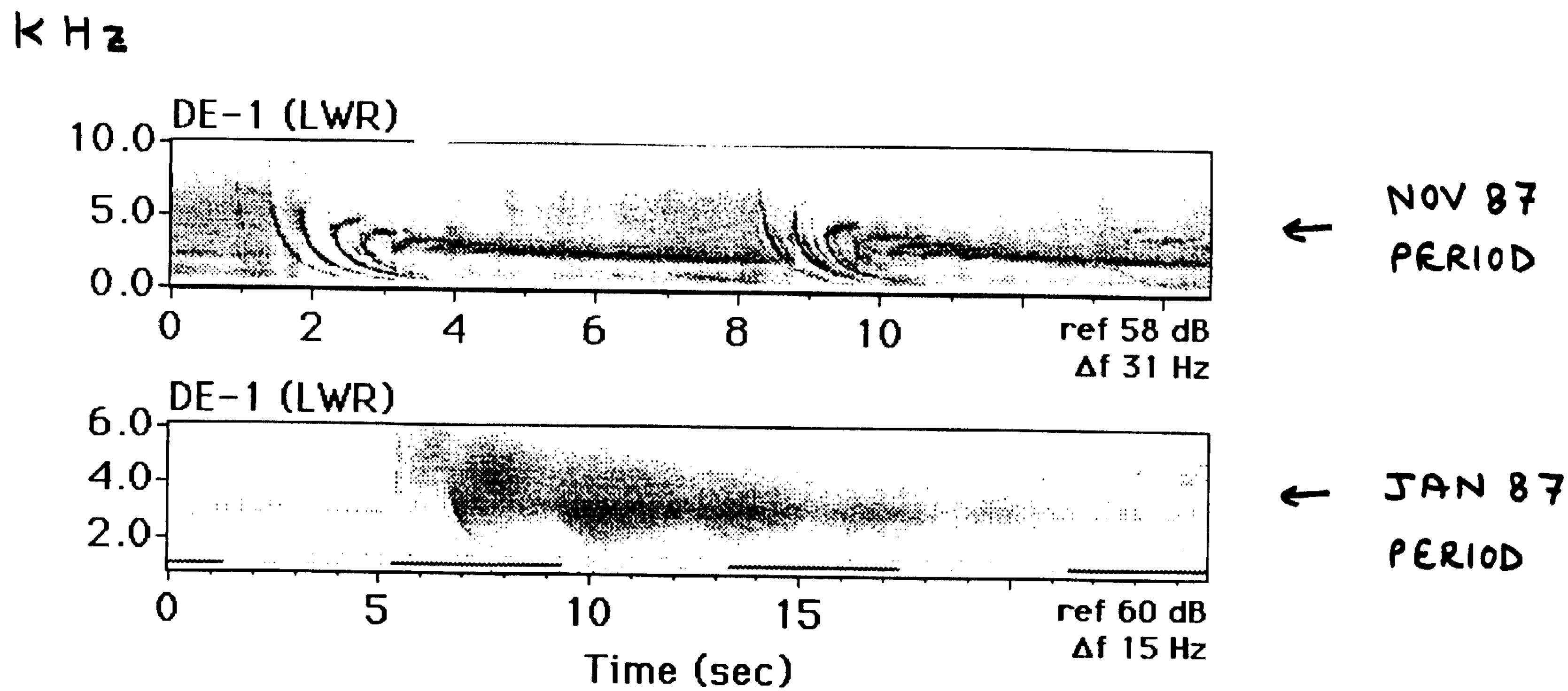
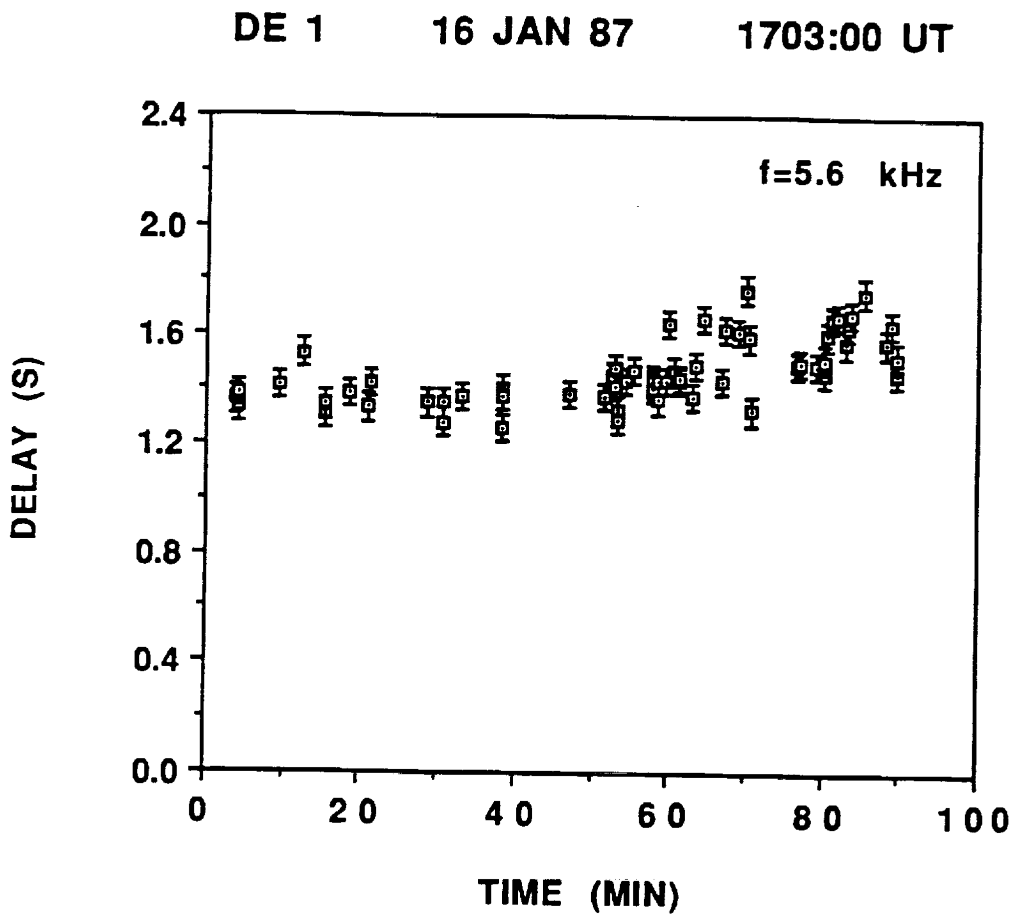
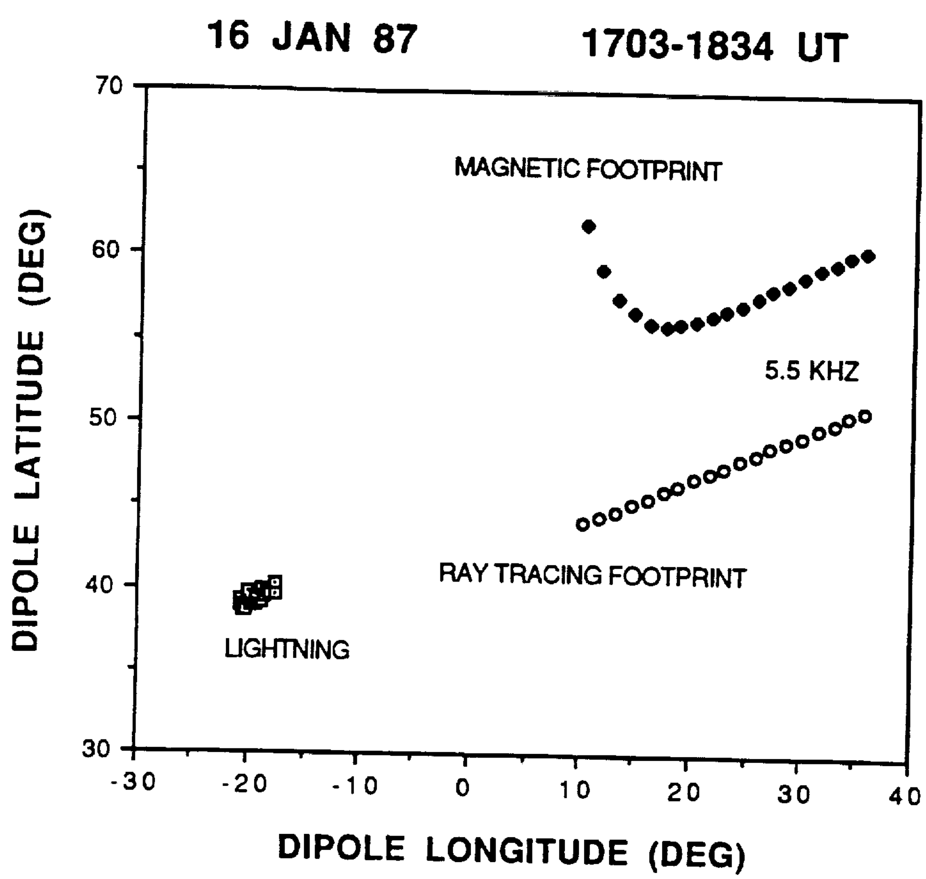

KHz
DE-1 (LWR)
10.0
5.0
0.0
0
2
4
6
8
10
ref 58 dB
Δf 31 Hz
DE-1 (LWR)
6.0
4.0
2.0
0
5
10
15
ref 60 dB
Δf 15 Hz
Time (sec)
← NOV 87 PERIOD
← JAN 87 PERIOD

FIGURE 3



DE 1
16 JAN 87
1703:00 UT
f=5.6 kHz
DELAY (S)
2.4
2.0
1.6
1.2
0.8
0.4
0.0
0
20
40
60
80
100
TIME (MIN)

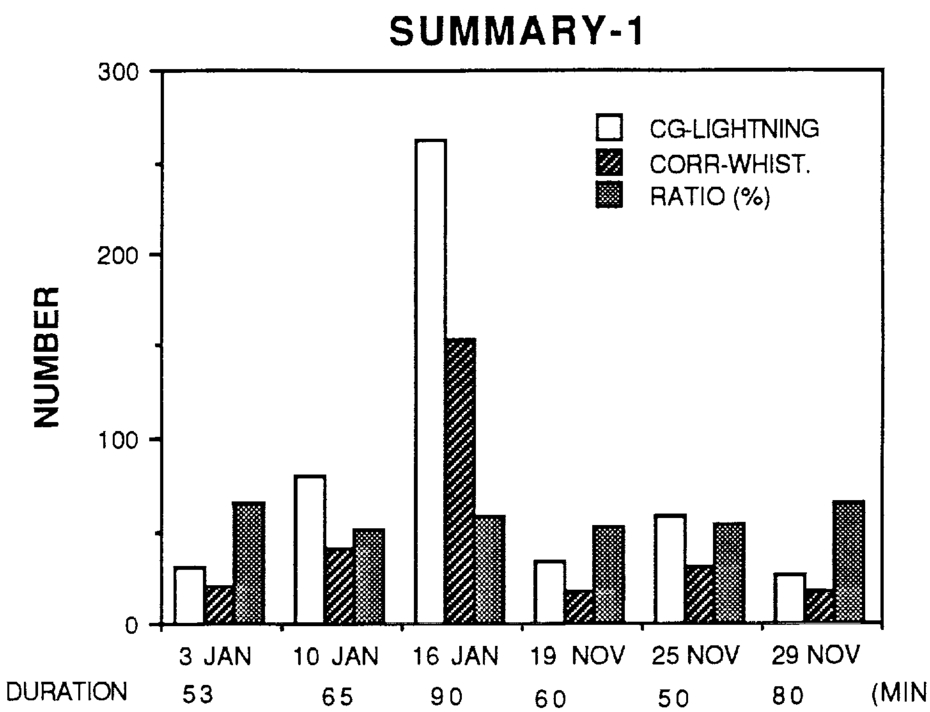
(a)



16 JAN 87
1703-1834 UT
MAGNETIC FOOTPRINT
5.5 KHZ
RAY TRACING FOOTPRINT
LIGHTNING
DIPOLE LATITUDE (DEG)
70
60
50
40
30
-30
-20
-10
0
10
20
30
40
DIPOLE LONGITUDE (DEG)

(b)

FIGURE 4


SUMMARY-1
300
200
100
0
NUMBER
CG-LIGHTNING
CORR-WHIST.
RATIO (%)
3 JAN
10 JAN
16 JAN
19 NOV
25 NOV
29 NOV
DURATION
53
65
90
60
50
80
(MIN)