THE RELATIONSHIP BETWEEN THE BACKGROUND AND TRANSIENT SIGNALS IN SCHUMANN RESONANCES

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ABSTRACT: Two distinct measures of the Earth's Schumann resonances--the background and the transients-- are studied through comparisons at the mesoscale and at the continental scale. A rough proportionality is shown between the far more abundant afternoon lightning activity and the larger positive mesoscale discharges that make sprites and simultaneously ring the Earth-ionosphere cavity to levels higher than the integration of all other lightnings.

INTRODUCTION

The Schumann resonances of the Earth-ionosphere cavity provide a natural framework for global lightning studies from one or a few measurement sites. The 'background' and 'transient' resonsnces are distinct aspects of the same electromagnetic phenomenena. Historically, they have been investigated independently, with a few notable exceptions (Ogawa et al, 1966; Fellman, 1973; Lazebnyy and Nickolaenko, 1975). The twofold interest in global climate signals and the optical phenomena (sprites/elves) in the mesosphere (with which large positive SR lightning transients are associated) have reawakened interest in both aspects of SR. This study is concerned with the physical relationship between the background and the transient SR phenomena. This relationship is explored at the mesoscale in North America with observations of sprites and lightning from the National Lightning Detection Network (NLDN), and on a tropical continental scale (Africa, S. America) with single station SR measurements from West Greenwich, RI. The results support the idea that the background resonances are driven largely by lightning in late afternoon thunderstorms, and the transients are dominated by more energetic lightning in mesoscale convective systems (MCS') that predominate later in the diurnal cycle. A close relationship is found between these two lightning types on a global basis.

MESOSCALE COMPARISONS

In an earlier study of positive ground flashes (CG's) during the End of Storm Oscillation in several Florida MCS' (Williams and Boccippio, 1993) it was noticed that larger numbers of late afternoon flashes were associated with larger numbers of positive CG's in the late evening. A later discovery (Boccippio et al, 1995) linked energetic positive CG's with both mesospheric sprites and Schumann resonance transients. To further clarify and quantify these relationships, further studies were carried out on MCS' in the Great Plains for which sprite observations and ground flash documentation by the NLDN were also available.

Storms were selected for which the sprite observation periods from the Yucca Ridge Observatory were reasonably complete and for which NLDN observations were available from beginning to end. The CG lightning history was determined by making 1000km scale NLDN maps at 30 minute intervals and then tracking forward and backward in time to identify the beginning and end of the CG activity. This analyis also enabled the selection of physical boundaries of the storms, which were checked against the Yucca Ridge logs to verify that sprites occurred over the respective lightning regions.

Total sprite counts against total flash counts are plotted for four MCS' in Fig 1a and sprite counts against positive CG counts appear in Fig 1b. Positive correlations are evident in both cases. The results in Fig 1b suggest that approximately one in every ten positive CG's produces a detectable sprite. The overall results in Fig 1 support a proportionality between CG lightning and both sprite and positive CG production.

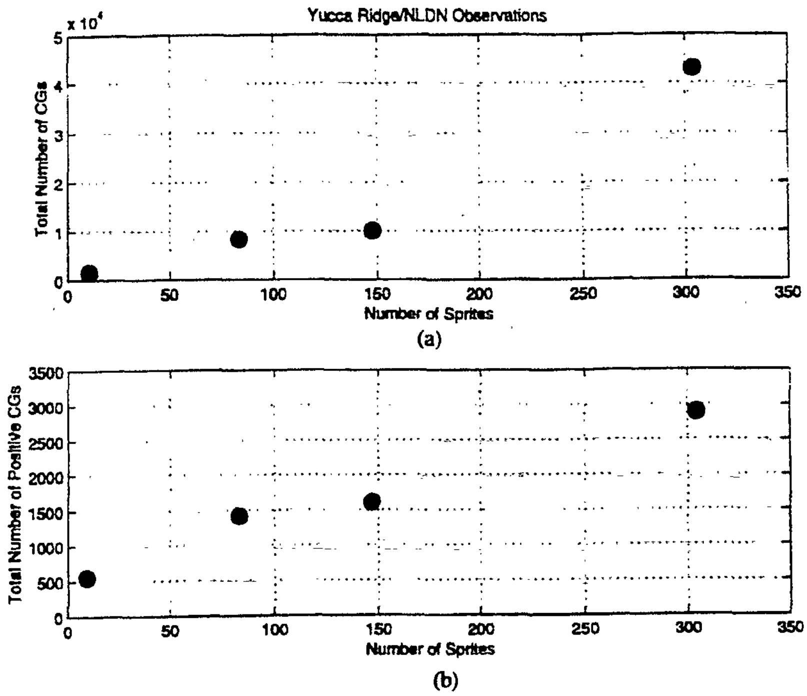

Figure 1 a)Total CG count vs total sprite count and b) Total positive CG count vs total sprite count.

CONTINENTAL SCALE COMPARISONS

A study of these lightning interrelationships on a global basis has been enabled by SR observations from MIT's ELF station in Rhode Island. Methods for analyzing both the background (Heckman et al, 1998) and the transients (Huang et al, 1999) have been described in some detail. The goal here is to combine the methods to compare background and transient response on individual days over Africa and S. America.

From the Rhode Island station, Africa lies nearly due east on a great circle path and S. America is south. If isotropic waveguide response is upheld, we expect the horizontal magnetic field from vertical lightning current in Africa to have a dominant NS component in RI. Likewise, the S. American lightning is expected to produce a dominant EW magnetic field. These predictions are consistent with the RI observations (in winter months when the global sources are well removed from the RI receiver) and with the classical behavior of the global electrical circuit (Whipple, 1929).

Fig 2 shows observations on a fairly typical winter day (Dec 14, 1996) in Rhode Island. Fig 2a shows the magnetic intensity variation on the NS magnetic coil and Fig 2b shows the EW intensity. The NS intensity is observed to peak at 15-16 UT, consistent with the well established time for late afternoon African lightning activity. Likewise, the well defined background maximum in the EW record is found at 20 UT, the approximate time for late afternoon activity in that continent.

Superimposed on the respective background curves in Fig 2 are the diurnal variations of the numbers of large positive transients mapped from Rhode Island in Africa (Fig 2a) and in S. America (Fig 2b) on the same day (Dec 14). (The acceptance criterion for a transient is a correlation coefficient between theoretical and measured wave impedance spectrum of 0.65 or greater.) Similar phase relationships between background and transient activity are apparent in both continents, with the transient activity lagging by several hours the maximum background intensity.

The number of S. American transients satisfying the acceptance criterion exceeds that of the African transients by more than a factor of 20. This result is attributable to waveguide attenuation and the strong decline in the distribution function of charge moments. Part of this 20-fold difference can be explained by the'slow tail' energy available in S. American events but largely dissipated in the case of African events, as discussed in Huang et al (1999).

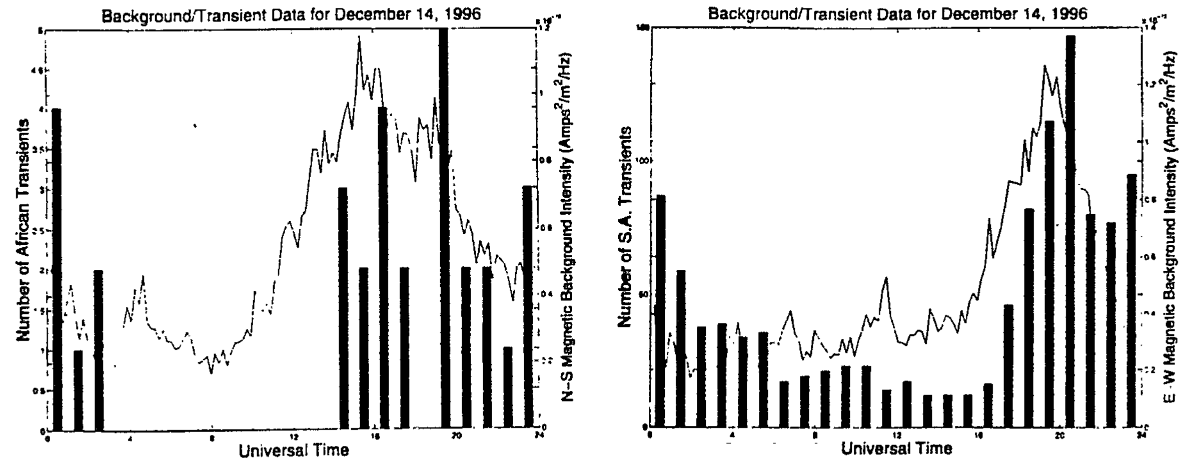

Figure 2 a)NS magnetic intensity and Africa transients, b) EW magnetic intensity and S.A. transients

To further quantify the relationship between the background and the transients, observations on 40 days were selected from December 1996, January 1997, and February 1997 for which both records were reasonably 'clean'. Figures 3 a and b show scatter plots of the daily number of positive transients versus the daily maxima in background intensity, for the African and S. American zones, respectively. Strong positive correlations are evident in both cases.

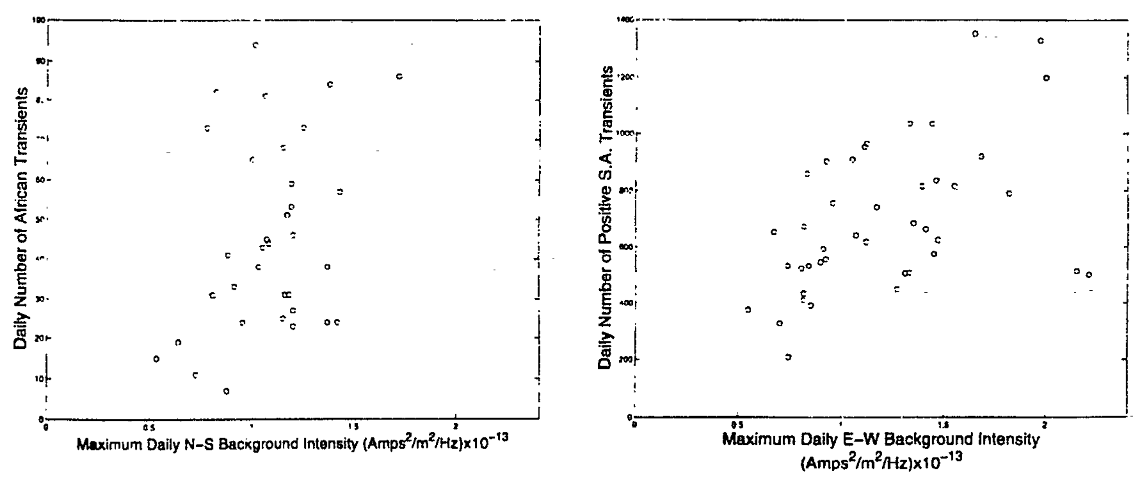

Figure 3 Background intensity vs daily transient counts for a) Africa and b) South America.

DISCUSSION

Three previous investigations of the relationship between the background and the transient SR were carried out more than 25 years ago without detailed knowledge of large positive ground flashes, mesospheric sprites, or the MCS' with which these extraordinary events are associated. Nor did these earlier investigators possess extensive capability for mapping the transients. Nevertheless, the earlier results on the distinct regional diurnal variations of the background and transient signals (Ogawa et al, 1966; Lazebnyy and Nickolaenko, 1975) agree with the present findings. Furthermore, the general finding that the background and transient signals are closely coupled (Fellman, 1973) stands out clearly in the present results. This study differs from that of Lazebnyy and Nickolaenko (1975) in the sense that our UT diurnal variations of transients is not flat and our transient populations, like the background signals, are dominated by continental regions.

The rough proportionality between the intensity of the background SR (representing the integration of ordinary afternoon lightning) and the numbers of large positive transients (mesoscale lightning later in the diurnal cycle) is welcome news to students of SR. This result suggest that the tail of the global lightning distribution (which is mappable from a single SR station) should serve as a quantitative measure of the total lightning distribution (which is more difficult to map from one or several stations).

CONCLUSION

Based on both mesoscale and continental scale comparisons, the number of positive ground flashes and sprites is roughly proportional to the total lightning activity earlier in the diurnal cycle. Convective scale thunderstorms in the late afternoon which drive the background SR aggregate later in the diurnal cycle to form large mesoscale charge reservoirs. The large charge reservoirs are needed to make the energetic lightning flashes whose ELF signals stand out above all the others smaller lightning flashes.

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ACKNOWLEDGEMENTS

These studies have been supported by the Physical Meteorology and Climate Dynamics Sections of the National Science Foundation (Grant ATM 963 3766), with assistance from J. Fein, R. Rogers, and R. Taylor. We thank T. Mitchell of the University of Rhode Island for continued use of the Rhode Island field station.