COMPARISONS OF LONG-TERM SCHUMANN RESONANCE RECORDS IN EUROPE AND NORTH AMERICA

G. Sátori[1], E.R. Williams[2], B. Zieger[1], R. Boldi[3], S. Heckman[1], K. Rothkin[2]

[1]Geodetic and Geophysical Research Institute, Sopron, HUNGARY
[2] MIT, Parsons Laboratory, Cambridge, Ma. U.S.A.
[3] MIT, Lincoln Laboratory, Lexington, Ma. U.S.A.
[4] NASA, Hunstville, Alabama, U.S.A.

ABSTRACT: Two stations at a distance comparable with the wavelength in the Schumann resonance (SR) frequency range, one in Europe (Nagycenk, Hungary) and one in North America (West Greenwich, Rhode Island) have simultaneously monitored the natural vertical electric and horizontal magnetic field components in the frequency range of 3-25 Hz. This is a unique opportunity, as Schumann resonance stations are scarce and even fewer station have records with 5-6 year durations. The main purpose of this paper is to make comparisons in the SR time series measured simultaneously at the two field site, thereby providing access to global behavior on the seasonal and interannual time scales. The comparative measurements described here point out distinct differences in the nature of convection in South America and in Africa, and reveal new aspects about the behavior of tropical continental convection on the ENSO time scale.

INTRODUCTION

Long term comparative measurements of the global electrical circuit have historically been quite scarce on account of local noise problems and the difficulty in obtaining measurements of ionospheric potential on a continous basis. Schumann resonance measurements largely overcome both these difficulties, and a growing interest in global change has encouraged new monitoring efforts. The major cornerstone of atmospheric electricity has been constructed around the universal diurnal cycle of global tropospheric convection. In this paper, coordinated measurements at remote locations in Hungary and in Rhode Island for a 6 year period are used to investigate aspects of global convection on the seasonal and the interannual time scales.

INSTRUMENTATION-METHODOLOGY

In each field station a ball antenna and two induction coils are used for the measurement of the vertical electric field component and the horizontal magnetic field components, respectively. Spectral analysis applied by the two observatories are different. The actual peak frequencies of the first three modes and the corresponding amplitudes are determined by the complex demodulation technique at Nagycenk (NC), whereas Fourier analysis is applied to compute the spectral powers, and Lorentzian spectral fits are then used to determine the frequencies and the Q-factors for the first eight resonance modes in Rhode Island (RI).

COMPARISONS

Figure 1 shows the geographical position of Nagycenk and West Greenwich with respect to the main tropical thunderstorm regions. Africa is the dominant source region for the European observatory and South America for the North American field site.

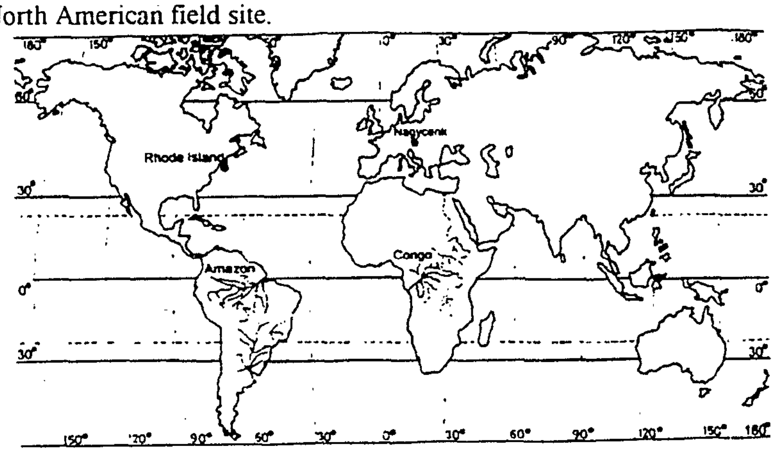


Figure 1. The geographical position of the two SR observatories (Nagycenk, Hungary and West Greenwich, Rhode Island) showing also the Amazon and Congo regions.

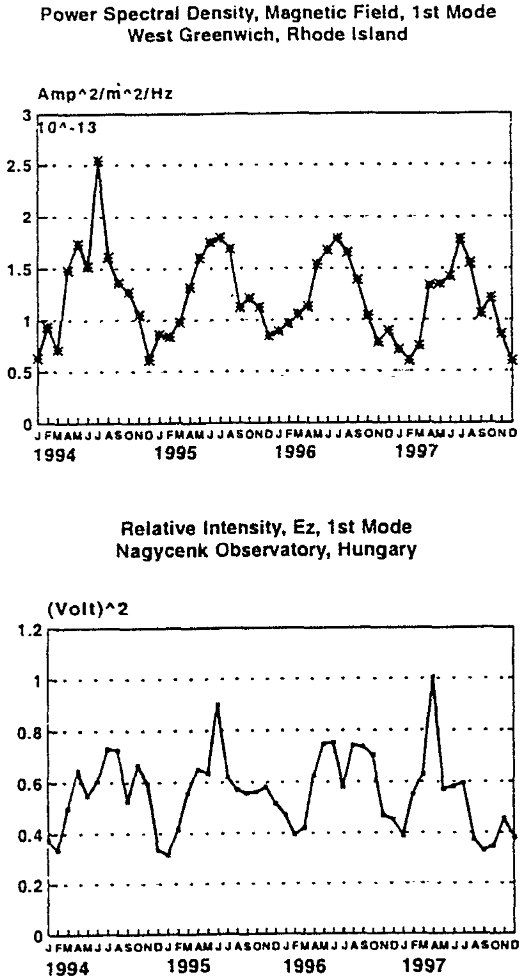


Figure 2.

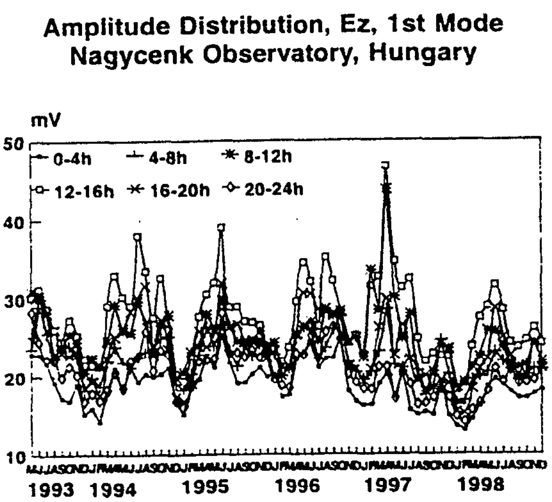


Figure 3.

The Ez records in Hungary and magnetics in Rhode Island are clearly consistent in amplitude and phase on the annual time scale, as indicated by Fig.2. The maxima in NH summer and the approximate factor-of two overall variation are consistent with ongoing observations of lightning from space with the Optical Transient Detector (OTD). The relative roles of source proximity effect and intrinsic source variation remain an issue for this time scale as well, and it is likely that their relative contributions are different at the two locations. The North American source is particularly strong in summer, perhaps as strong as any tropical source *Füllekrug and Fraser-Smith* [1998]. A portion of the substantial SR intensity variation is attributable to the source proximity effect in Rhode Island while the majority in Hungary is likely due to intrinsic variation of the global lightning activity. The signature of the tropical semiannual temperature variation is well pronounced in the vertical electric field component at Nagycenk [*Sátori and Zieger,* 1996] with maxima near equinox months in 1993, 1994, 1995 and 1997 but with different magnitudes in different 4-hour segments of the UT day as shown in Fig.3. The most pronounced semiannual signal is found in the 12-16 UT interval and lends further evidence for Africa as the primary source of the latter signal. Only a weak indication of the semiannual variation is present in the Rhode Island record. Figure 4. shows the annual and semiannual sinusoidal components of the SR intensities for Rhode Island (line with stars) and Nagycenk (line with circles) extracted by digital filtering technique. As each time series was normalized by its own median value both the magnitudes and phases are comparable.The annual wave is dominant for RI and they are almost in phase in the two stations with summer maxima, the semiannual waves with near equinoxial maxima are present only in Nagycenk records. The phase of the semiannual wave with summer (winter maxima) at RI implies its subharmonic nature without physical meaning. Figure 5. shows the filtered semiannual waves in the 12-16 UT and 20-24 UT intervals at Nagycenk. Their magnitudes are higher in that time interval when Africa dominates the lightning activity. Even the smaller late evening semiannual signal is rather attributable to the rest activity of Africa than South America.

Measurements of the horizontal magnetic field components were also started in Hungary at the end of 1996. Figure 6a,b show that the semiannual waves with near equinoxial maxima are also present in magnetics in this European station.

The distinct differences in semiannual behaviour between Hungary and Rhode Island naturally invited a closer examination of the respective source regions.

The two largest rivers in the world (by discharge volume) drain these two source regions: the Amazon and the Congo. The limits of the Amazon basin correspond closely with Brazil's borders and likewise the Congo is largely contained within the former Zaire. Hydrological [*Amerasekera et al.*, 1997] and climatological meteorological information for these two countries [*Marques*, 1992; and *de Halleux*, 1979] have therefore been compared to shed light on the semiannual component on a scale appropriate for the global Schumann resonances.

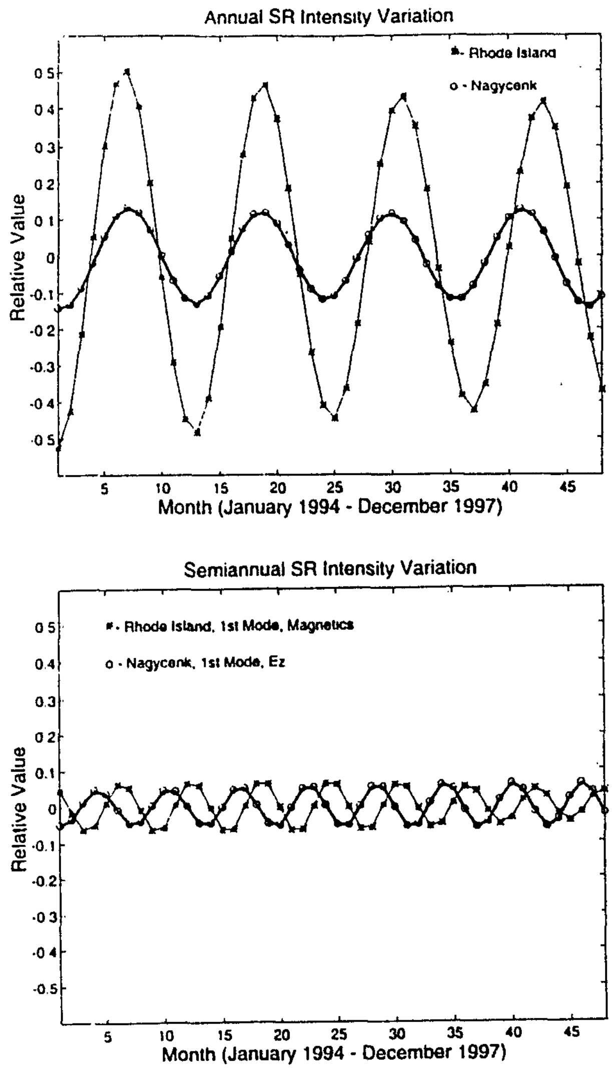


Figure 4. Annual-semiannual SR intensity variations extracted by filtering technique. (above)

Marked differences were found in the comparisons of seasonal maximum surface air temperature, with nearly all stations in Zaire showing double-peaked seasonal behavior, whereas fewer than 20% of 26 stations within 5 degrees of the equator in Brazil showed such an effect. Seasonal variations of rainfall [*Figueroa and Nobre*, 1990] likewise show a far more prevalent characteristic in Zaire than in Brazil. On a basin scale, the collective behavior is self consistent: the seasonal discharge record for the Congo is double-peaked, whereas the Amazon record shows a single broad maximum in July with little hint of semiannual behavior.

The physical explanation for the marked differences in Schumann resonance intensity documented in Fig.2 and Fig.4 may lie in the hydrological observations [*Meade et al.*, 1991 and *Amerasekera et al.*, 1997]. The difference in annual precipitation between these two great basins is only 30% but the runoff to rainfall ratio for the Amazon is 2.5 times greater than for the Congo. This observation suggests that the Amazon basin is much closer to fluid saturation (and hence prone to greater runoff) than the Congo. This also strongly suggests that Amazon (and the South American continent of which the Amazon is a large piece), will behave more like an ocean than a land surface, and hence respond less strongly than Africa to the well known semiannual variation in solar insolation in the tropical region [*Williams*, 1994]. The tropical oceans show very little response on the semiannual time scale. The contrast in convective response in Africa and Brazil on the semiannual time scale is consistent with the like contrast in their response on the diurnal time scale [*Park*, 1990] .

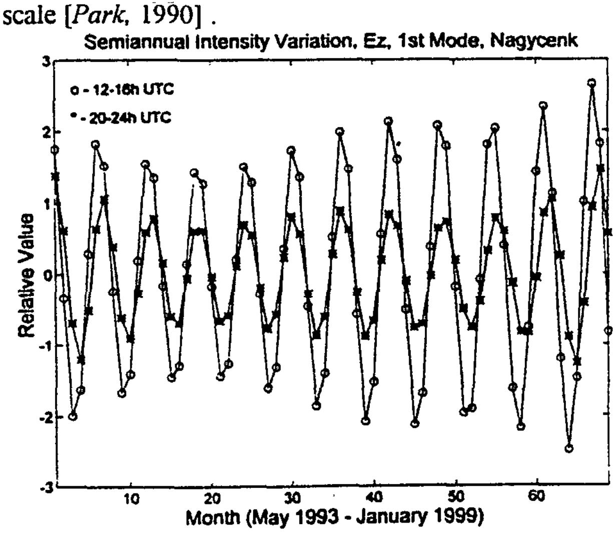
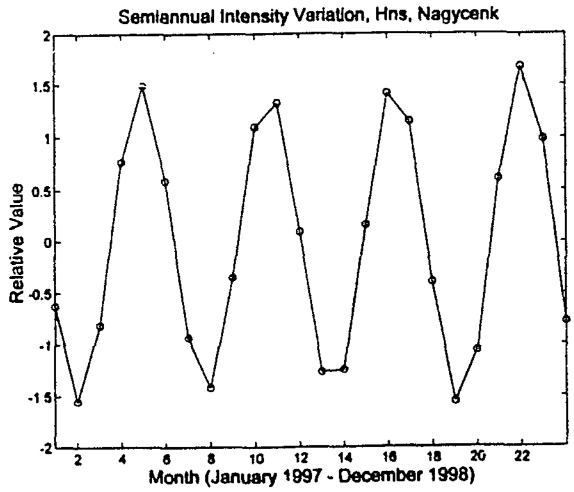


Figure 5. Semiannual waves of Ez at Nagycenk filtered for different segments of a day. (right)



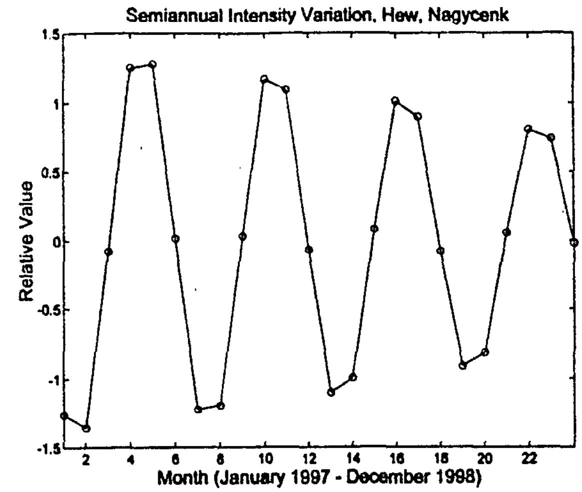


Figure 6. Semiannual intensity variations of the magnetics at Nagycenk extracted by filtering technique.

The interannual variation in SR intensity with a moderate increase in 1996 (see Fig.2) is correlated between the two stations, but is undramatic in comparison with the seasonal changes already discussed. The dominant contributor to interannual variability in the tropics, where lightning is most prevalent, is the El Niño phenomenon. Despite vigorous ENSO activity during the 1993-1998 period of coordinated SR measurements, the strong in-phase relationship between SR intensity and tropical temperature found earlier by *Williams* [1992] for an earlier epoch, is not apparent. In fact, in the present record, the behavior is opposite: the electric intensity in Hungary was low in the previous warm epoch (1993, 1994), high during the cool 1996, and again low in the latest intense warm El Niño phase between March 1997 and April 1998. Then it began to incrase in the recent cool La Niña phase (see Fig.3). Based on SR frequency and intensity observations at Nagycenk, *Sátori and Zieger* [1999] suggest meridional shifts of lightning activity in global sense with a southward (northward) displacement in the warm (cool) phase of the ENSO.

ACKNOWLEDGEMENT: Discussion with E. Eltahir on issues of hydrology are much appreciated. This research was supported by the U.S.-Hungarian Joint Found, JF554 and the Hungarian Science Foundation, T023111.

REFERENCES

Amerasekera, K.N., R.F. Lee, E.R. Williams and E.A.B. Eltahir, ENSO and the natural variability in the flow of tropical rivers, *J. Hydrology, 200*, 24, 1997.

Ergo, A.B. and B. de Halleux, Catalogue Mondial des Donnees Climatiques Moyennes, Vol. II-L'Afrique, Fascicule I.,Premiere partie: Zaire, Musee Royal de L'Afrique Centrale, Tervuren, Belgium, 225 pp., 1979.

Figueroa, S. N. and C. A. Nobre, Precipitation distribution over Central and Western Tropical South America, *Climanalise*, 5(6), 36-45, 1990.

Füllekrug, M. and A.C. Fraser Smith, Global lightning and climate variability inferred from ELF magnetic field variations, *Geophys. Res.Letter*, 24(19), 2411-2414, 1997.

Marques, J.C., Normais Climatologicas (1961-1990), Departamento Nacional de Meteorologia (INMET), Brasilia, Brazil, 84 pp., 1992.

Meade, R.H., J.M. Rayol, S.C. Da Conceicao and J.R.G. Natavidade, Backwater effects in the Amazon River Basin, *Envir. Geol. Water Sci.*, 105-114, 1991.

Park, S., ISCCP Satellite Observations of the Diurnal Variation of Deep Tropical Convection, Master's Thesis, Center for Meteorology and Physical Oceanography, 1990.

Sátori, G., and B. Zieger, Spectral characteristics of Schumann resonances observed in Central Europe, *J. Geophys. Res., 101*, 29,669, 1996.

Sátori, G., and B. Zieger, El Niño related meridional oscillation of global lightning activity, *Geophys. Res. Letter*, in press, 1999.

Williams, E. R., The Schumann resonance: A global tropical thermometer, *Science, 256*, 1184, 1992.

Williams, E. R., Global circuit response to seasonal variations in global surface air temperature, *Mon. Weather Rev., 122*, 1917, 1994.