Finding Schumann resonance transients using an automatic method

T. Nagy[1], J. Bór[1], M. Neska[2], G. Sátori[1]

[2] *Research Centre for Astronomy and Earth Sciences, GGI, Hungarian Academy of Sciences, Csatkai u. 6-8., 9400 Sopron, Hungary*

[2] *Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland.*

Schumann-resonance transients (SRTs) are excited by energetic lightning strokes. They appear as coherent signals with large amplitudes superimposed on the background electric and magnetic field components. These energetic lightning strokes are often accompanied by TLEs (Transient Luminous Events) therefore determining space and temporal distribution of these exceptional lightning flashes by SR transients can be important from the point of view of TLE productivity in the active thunderstorm areas of the world, especially in the three tropical chimney regions (America, Africa, Asia). First the method for finding SR transients automatically is presented and then comparisons between the variation of background SR intensity and the number of SR transients on the diurnal time scale observed in the SR stations at Nagycenk, Hungary and Belsk, Poland is shown.

1. Introduction

The lower ELF (Extremely Low Frequency) range (< 100 Hz) is known as the Schumann resonance (SR) band. SRTs excited by energetic lightning strokes can be analyzed on a global basis from single observation sites. Global mapping of lightning based on SR measurements at Rhode Island, USA is presented in [1]. Distribution of SRTs are very similar to the global lightning distribution deduced from background SR [2]. The purpose of this presentation is to study the relationship between the background SR intensity and its SRT productivity varying in space and time.

2. SRT detection

SR have been measured at Nagycenk (NCK), Hungary since 1993 and Belsk (BLK), Poland since 2005. Both the vertical electric and horizontal magnetic field (north-south and east west directions) components are measured in the frequency range, ~3-30 Hz and the same spectral technique (complex demodulation) is used for processing the background SR in the two stations [2,3].

In principle, the same number of SRTs should be found in the SR time series in both stations in a common time period. Figure 1 shows a SRT elevating from the background SR field components recorded at NCK. The time markers are indicated in every 100 ms. The two impulses following each other in the E_Z field component correspond to the direct as well as the anti-podal waves propagating from the "lightning-antenna" to the observing site.

Mathematically speaking, we have a 3-dimensonal time series at both sites.

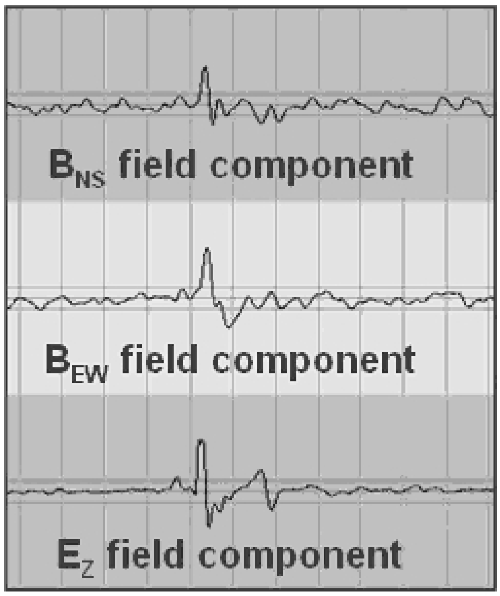

Fig.1 SRT elevated from the background SR field components observed at Nagycenk, Hungary

SRTs have a characteristic wave form which is recognizable fairly easily after visually exploring the data (observe the quite typical pattern near the middle of Fig. 1.). Based on such pattern we can obtain valuable information about the parent stroke of SRTs (location, polarity, charge moment changes). It would be a tedious work to find SRTs manually in our registration due to their large number in a day. Therefore we developed an automatic method to perform this task. In the following, we provide a brief description of it.

3. Methodology

With a properly chosen resampling strategy, we can achieve that a SRT pattern becomes a single spike in the resampled data. After pre-whitening each component separately and standardizing them we apply a further transformation to reduce the dimensions of the time series from 3 to 1. This transformation is chosen so that an SRT pattern in the original 3-dimensional time series becomes an outlier in the resulting univariate one.

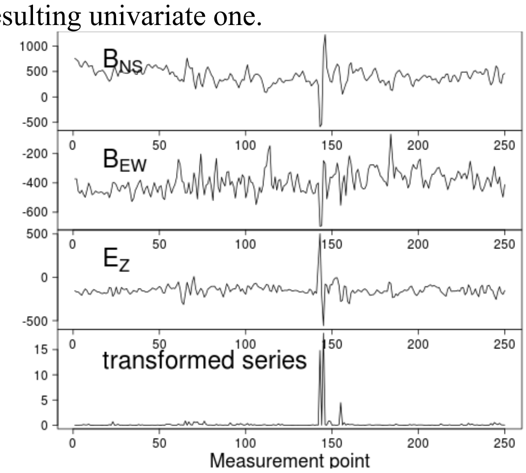

Fig.2 SR time series (5s) recorded at BLK with the transformed time series added as the 4th component.

Therefore we can use univariate outlier detection techniques to search for the location of SRTs in the time series. One very simple, but in practice efficiently and sufficiently working method of such is handling our time series as if it consisted of observations from an independent, identically distributed sample. Based on the data, we can estimate this hypothetical distribution and classify an observation as an outlier if it belongs to the upper or lower tail of this distribution determined by a predefined significance level.

4. Results and discussion

Figure 3 shows the diurnal variation of the background SR intensity and SRT distribution found by the method applied here. The relation of their variations will be presented in different time scales (day, month, season) at the two stations to disclose the time variation of SRTs with respect to the background. SRT distributions excited by parent strokes with different polarities will also be presented.

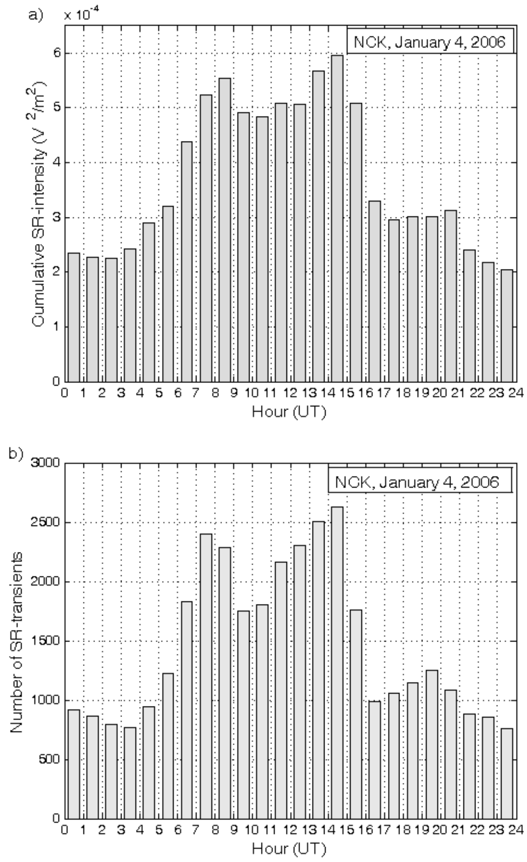

Fig.3 a) Variation of cumulative SR intensity (first three modes) and b) SRT distribution at NCK, January 4, 2006.

5. References

[1] Y. Hobara, M. Hayakawa, E. Williams, R. Boldi & E. Downes, M. Füllekrug, E. A. Mareev & M. J. Rycroft (Eds.), Location and Electrical Properties of Sprite-producing Lightning from a Single ELF Site, Sprites, Elves and Intense Lightning Discharges, Springer Netherlands, 225, 211-235, 2006.

[2] G. Sátori, J. Szendrői, and J. Verő, Monitoring Schumann Resonances–I. Methodology, Journal of Atmospheric and Terrestrial Physics, 58(13):1475 – 1481, 1996.

[3] M. Neska, G. Sátori, J. Szendrői, J. Marianiuk, K. Nowożyński, and S. Tomczyk, Schumann Resonance Observation in Polish Polar Station at Spitsbergen and Central Geophysical Observatory in Belsk, Publs. Inst. Geophys. Pol. Acad. Sc., C-99(398), 2007.