AREAL VARIATIONS OF THE WORLDWIDE THUNDERSTORM ACTIVITY ON DIFFERENT TIME SCALES AS SHOWN BY SCHUMANN RESONANCES

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ABSTRACT: Long-term Schumann resonance frequency records at Nagycenk (NC), Hungary have been used to determine areal variations of the worldwide thunderstorm activity on daily, seasonal, annual and interannual time scales. The daily frequency range (DFR) of Schumann resonances (SR) is the band in which the resonance frequency shifts up and down during a day. The DFR is related to the size of the region where the random lightning discharges are distributed. The wider, the region is, the smaller the DFR becomes, and vice versa. The mean size (diameter) of thunderstorm regions can be obtained from the DFR using a calibration curve characteristic of the SR station at NC. Daily and monthly means of source diameter were determined from May 1993 up to December 2002. A series of band-pass filter were applied to construct dynamic spectra of DFR for the first and second SR modes. Numerous periods appeared in the range of periods from 2 days up to one year. The 13.5 day (half solar rotation period) areal variation deduced here might be generated by tropospheric influences of extraterrestrial origin. All other periodicities of lightning areas deduced from DFR of SR may be driven by tropospheric processes. The annual areal variation is a response to the north-south asymmetry of the land-ocean distribution. The semiannual areal variation can be explained both by the semiannual tropical land surface temperature variations and the thermal instabilities in the transition seasons (spring and fall). The annual and semiannual areal variations as well as the periods longer than 10 days show clear, long term (decadal) modulations which might be attributed to the dependence of the worldwide lightning area on the 11 year solar-cycle.

INTRODUCTION

The daily frequency range (DFR) of Schumann resonances (SR) is the band in which the resonance frequency shifts up and down during a day as indicated by arrows in Fig.1. The DFR is related to the size of the region where the random lightning discharges are distributed. The wider, the region is, the smaller the DFR becomes, and vice versa [Nickolaenko et al., 1995].

Figure 1. Mean diurnal frequency variations in the four seasons in case of the 1st (left) and 2nd (right) modes of the vertical electric field component observed at Nagycenk, Hungary.

The daily frequency patterns are different for the different modes and seasons as shown in Fig.1. The daily frequency pattern depends on the source receiver geometry which changes in a day and it is different in the different seasons. This is the reason of the seasonal variation. The daily frequency pattern are determined by special (nodal) angular distances which are different for the different
modes. This means that the daily frequency pattern of the 1st and 2nd modes are not equally responsive for the different source regions. However the daily frequency range (DFR) of the two modes, in which the resonance frequency shifts up and down, exhibits common variations month by month, season by season and year by year. As the DFR is indicative for the thunderstorm area, the two modes practically scan the area of all active thunderstorm regions in a day and yield a mean areal parameter referring to a mean thunderstorm region active at around 16h LT. This daily „single source” is presented in Fig.2 where the local time variation of lightning activity averaged over the globe from Optical Transient Detector (OTD) data for one year period from September 1995 to August 1996.

![Figure 2. Local time variation of global lightning activity in a year observed by OTD [Blakeslee et al., 1999]](image)

**DATA ANALYSIS**

The calibration curve shows the relationship between the DFR and the source diameter given in hours. One hour corresponds to 15° angular distance. It is assumed that the lightning discharges are uniformly distributed in a single circular area with diameter measured in hours or angular distances. The centre of the area moves uniformly along the equator, and the diurnal frequency variations can be observed at NC. The ionospheric propagation constant at resonance frequencies were calculated from experimental data [Bliokh et al., 1980]. The frequency dependence of the propagation constants in the whole frequency range was calculated using an interpolation and extrapolation procedure [Nickolaenko et al., 1998].

![Figure 3. Calibration curves for computing DFR at Nagycenk station.](image)

Time series of DFR were built up from the monthly mean diurnal frequency variations in case of the 1st and 2nd SR modes of the vertical electric field component at NC. Time series of DFR were transformed to time series of areal variations by using the calibration curves shown in Fig.3

![Figure 4. Areal variation of the worldwide thunderstorm activity month by month deduced from DFR in case of the 1st mode (curve with circles) and 2nd mode (curve with stars). The bold curve shows the mean areal variation.](image)
The annual mean of source diameters seems rather stable year by year as shown in Fig. 5.

However the annual and semiannual areal variations of the worldwide lightning activity deduced from DFR exhibit well pronounced decadal (solar cycle) modulation.

Figure 5. Annual means of lightning area deduced from DFR from 1993 to 2001

Figure 6. Sunspot numbers indicating the solar activity during the years studied here

Figure 7. Decadal (solar cycle) modulation of the semi-annual areal variation determined by two different methods (a. filtering b. least square fitting)

Figure 8. Decadal (solar cycle) modulation of the annual areal variation determined by two different methods (a. filtering b. least square fitting)

Figure 9. Average spectrum of DFR

Figure 10. Average amplitude variation of dynamic spectrum of DFR from 1993 to 2002 for periods of 10-100 days (above) and for periods shorter than 10 days (below)
CONCLUSION

The annual areal variations of the worldwide lightning regions can be explained by the north-south asymmetry of the land-ocean distribution in the two hemispheres. Thunderstorms can cover larger land areas in the Northern Hemisphere summer than in the Southern Hemisphere summer. The semiannual areal variation of global thunderstorms with maxima in spring and autumn can be attributed both to the semiannual variation of the tropical land surface temperature and the thermal instabilities increased in the transition seasons. Periodical changes of lightning areas identified here at 20 days and around 5 days are thought of tropospheric origin. The 13.5-day areal variation deduced here might be generated by tropospheric influences of extraterrestrial origins. The 13.5 day periodicity is significantly present in the other SR parameters (amplitude, frequency) [Zieger and Sátori, 1999]. This period, as fundamental one (without 27 day periodicity, too), was identified in solar wind speed and geomagnetic activity by Mursula and Zieger [1996].

The annual and semi-annual areal variations (Fig.7 and Fig.8), as well as, the additional periodical areal changes longer than 10 days (Fig.10, upper panel) exhibit long-term (decadal) modulation which might be considered as an indication of extraterrestrial influences on the 11-year solar cycle. The magnitude of the modulation of the annual areal variation increases with increasing solar activity (Fig.8) while the semi-annual areal variation shows an opposite behaviour on the same time scale, its modulation follows rather the variation of galactic cosmic rays on the 11-year solar cycle (Fig.7). The opposite modulation of the annual and semi-annual areal variations on the solar cycle might again be explained by the north-south asymmetry of the worldwide lightning distribution. The thunderstorm areas extended up to the 60°N latitude in the Northern Hemisphere summer but they hardly reach the latitude 45°S in the Southern Hemisphere summer as shown by OTD (Optical Transient Detector) observations. The 11-year solar cycle variation of thunder days in Middle-Europe [Schlegel et al., 2001] and cloud cover observation over the United States [Udelhofen and Cess, 2001] support that more lightning can occur on the Northern Hemisphere summer at around solar maximum. However cloud cover observations over the oceans on the Southern Hemisphere indicate dependence on galactic cosmic ray intensity during solar cycles [Marsh and Svensmark, 2000]. The consequence of these two opposite effects can be the modulation of the annual variations of lightning areas on the 11-year solar cycle, namely lightning areas extend more northward in the Northern Hemisphere summer and are more compressed in the Southern Hemisphere summer at around solar maximum in global sense (see Fig.4).

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REFERENCES