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ATMOSPHERIC DISCHARGES AND SCHUMANN RESONANCES

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Abstract:
Atmospheric discharges are electrical breakdown in Earth's atmosphere. They are included conventional lightning and middle/upper atmospheric lightning also called as Transients Luminous Events (TLEs). TLEs is a set of mysterious electrical discharges commonly known as red sprites, blue jets, blue starters, gigantic jets, elves and halos. They are closely associated to thunderstorm's activity and conventional lightning and occur from top of the thunderclouds to the lower ionosphere. Previous experimental results show that together conventional lightning and some of TLEs radiate in Extremely Low Frequency (ELF) region of the spectrum (3-3000 Hz) and contribute to Schumann resonances (SR). The SR are global electromagnetic resonances excited within the Earth-ionosphere waveguide and occur in ELF region below 100 Hz with resonant frequencies around 8 Hz, 14 Hz, 20 Hz, 26 Hz, 33 Hz, 39 Hz, 45 Hz etc. SR measurements and analysis have a range of applications such as to know the space-time distribution of global lightning activity, global thunderstorm activity, the properties of lower ionosphere layers, the Earth surface and atmosphere temperature variations, and the properties of earthquakes as well as to do the studies of other celestial bodies. In this article, we shall review SR in detail along with their sources of production and their potential applications.
Keywords: Thundercloud, Lightning, Transient Luminous Events, Earth-Ionosphere Waveguide, Schumann Resonance, ELF

1. Introduction:

Atmospheric discharges are electrical breakdown that occur in our atmosphere. They include regular lightning discharges and recently discovered transient luminous events (TLEs) known as red sprites, blue starters, blue jets, gigantic jets and elves. It is well understood that the electrical activities in the Earth's atmosphere are powered by thunderstorms or thunderclouds. However, their exact mechanism is still a mystery. Thunderclouds are electrically charged structures having their top region positively charged and bottom region negatively charged. However, the charging mechanism of thunderclouds is still under investigation by researchers [1]. As soon as the electric field due to this accumulation of charges becomes more than dielectric strength of air, a sudden high electric current starts to flow along with some sound. This is referred to as lightning and accompanied sound is called thunder. In simple terms, lightning is the process of spontaneous momentary high-current electrostatic discharge, which is initiated in the cloud and the path usually stretches over kilometers in length [2]. When the discharge occurs between the positive charge centre and negative charge centre of the same cloud, it is called intra-cloud (IC) lightning, while those discharges that involve two or more clouds are known as inter-cloud or cloud to cloud (CC) lightning. IC and CC lightning account approximately 75% of the global lightning occurrences. The other type of lightning which involves Earth's surface is called cloud-to-ground (CG) lightning. CG lightning further is divided in four types of lightning namely (i) downward positive lightning (ii) downward negative lightning (iii) upward positive lightning and (iv) upward negative lightning. The downward negative lightning discharge is the most common and widely understood by the scientists. This accounts ~90% of all the CG lightning discharges. A statistical examination of lightning data reveals that nearly 1.4 billion flashes occur annually over the entire Earth [3]. This annual flash count translates to an average of 44 ± 5 lightning flashes occurring around the globe every second. Lightning occurs mainly over land areas, with an average land/ocean ratio of ~10:1. It was found that lightning activity is particularly pronounced over the tropics and that ~80% of all lightning flashes occur between 30° S and 30° N latitude [3].

TLEs are upper atmospheric lightning discharges which occur from top of the thunderclouds to the lower ionospheric region. Their duration ranges from <1 ms to 100 ms. TLEs generally are independent to each other, although sometimes they may occur simultaneously. Elves are very short lived (<1 ms) red emissions occur at the bottom of the ionosphere (between 75-95 km altitudes) and appear as rings of light that move radially outwards like ripples on a pond in a horizontal extent as much as 530 km [4]. Their vertical thickness is several km. It is found that elves are associated almost with all types of lightning discharges and believed that the intense electric field produced by electromagnetic pulses (EMPs) of lightning discharges generates them. Red sprites are mesospheric discharges that span the altitude between ~40-95 km and generally occur after strong positive CG lightning for a short time of ~10-100 ms. It is believed that as the positive CG lightning occurs and transfers the positive charge of the thundercloud to the ground, the negative charge left within the cloud creates electric field at higher altitudes. Just above the thunderclouds, the pressure is high so this electric field is not sufficient to produce any discharge, but at higher altitudes (60-70 km) the pressure is quite low so the electric field generates a discharge in the form of streamers called sprites. The other candidates of the TLEs family are blue jets, blue starters, and gigantic jets. Blue jets are blue colored emissions that originate at the top of the thunderclouds (~20 km) and propagate upwards with a velocity of ~112±24km/s in the shape of luminous expanding cone to altitudes of ~40 km. They last for a period of ~200-300 ms. Blue jets are not found in association with any type of lightning rather they occur over the regions of thunderstorms which are actively producing negative CG lightning and heavy hail activity. A similar phenomenon called blue starters also originate at the top of the thunderclouds and propagate with a velocity range of 27-153 km/s but terminate at an average altitudes of ~25.5 km. Gigantic jets are similar to blue jets and can propagate up to ~70 km high and are rare. A detailed description of TLEs is given in previous literature [4-7].

It is well known that lightning produces electromagnetic waves in a wide spectral range, but bulk of the radiation falls in extremely low frequency (ELF) and very low frequency (VLF) range. The maximum radiated energy peaks at 10 kHz. Some of the TLEs like red sprites also radiate in ELF region [8-10]. The ELF waves attenuate very low with distance (~0.5 dB/Mm), they can propagate up to large distances before decaying i.e. ELF radiation can propagate few times around the globe before dissipating. The conducting surface of Earth of conductivity $\sigma \approx 10^{-3}$ S m^{-1} and the lower edge of the ionosphere of conductivity range 10^{-4}-10^{-8} S m^{-1} form a cavity and acts as a resonator at ELF. The conductivity within the cavity is very low with values $\sigma<10^{-10}$ S m^{-1}. When ELF waves from lightning or other source propagate in the Earth-ionosphere waveguide/resonator in opposite direction (direct and around-the-globe waves) they become amplified at resonance frequencies due to constructive interference. The spectra observed as resonant peaks at the frequencies 8, 14, 20, 26, and 32 Hz is called Schumann Resonances (SR). The resonance peaks occur when the wavelength of ELF waves is comparable to the circumference of Earth (~40,000 km). Schumann in 1952 assumed Earth and ionosphere as perfect conductors separated with a distance which is much smaller as compared to radius of Earth. With these assumptions, he calculated the resonant frequencies of the Earth-ionosphere cavity as given below [11]

$$f_n = \frac{c\sqrt{n(n+1)}}{2\pi R} \qquad (1)$$

where, c is the velocity of electromagnetic waves in Earth-ionosphere waveguide and R is the radius of Earth.

According to eq^n (1), the fundamental SR mode corresponding to n=1 is ~10.6 Hz. The other subsequent modes for n=2, 3, 4, 5 and 6 comes out to be ~18.3, 25.9, 33.5, 40.9 and 48.4 respectively. However, experimental observations reveal that the fundamental and subsequent SR modes occur at little bit low frequencies as compared to predicted by eq^n (1). The observed peaks are also seen wider than expected. The reduction of SR frequencies along with wider peaks of the spectrum occurs due to the absorption losses by the ionosphere because of its finite conductivity. The observed average frequencies of the five lowest SR modes are, approximately, 7.8, 14.3, 20.8, 27.3, and 33.8 Hz, which fall in the Extremely Low Frequency (ELF) range [12]. As long as the properties of Earth-ionosphere waveguide remain same these frequencies also remain the same. However, the Earth's ionosphere may change due to strong solar activity and hence variations of SR can be seen accordingly. The electric and magnetic fields due to the propagation of electromagnetic waves in Earth-ionosphere waveguide by assuming Earth and ionosphere as perfect conductors can be calculated in spherical polar coordinates (r,θ,φ). The excitation source is represented as a vertical dipole with a current moment (Ids) located within the Earth-ionosphere cavity at θ=0 and r=R. The symbol "θ" is defined as source-observer distance (SOD) and measured in radians. The inner shell of Earth-ionospheric cavity is Earth and has a radius R and the radius of outer shell is R+h. Where, h is the height of the ionosphere. Using Maxwell's equations, the Electric and magnetic fields of waves are obtained as [13-15]

$$E_r = i\frac{Ids}{8\pi R^2 \varepsilon_0 f}\frac{\nu(\nu+1)}{h}\frac{P_\nu^0(-\cos\theta)}{\sin\nu\pi} \qquad (2)$$

$$H_\varphi = -\frac{Ids}{4Rh}\frac{P_\nu^1(-\cos\theta)}{\sin\nu\pi} \qquad (3)$$

In the above equations (2 & 3), I is the average current in the source dipole; ds is the length of source dipole; ε_0 is the permittivity of free space; P_ν^0 and P_ν^1 are the associated Legendre functions with complex subscript; ν is the complex eigen value which describes the propagation and dissipation characteristics of the atmosphere as a function of frequency; and i is the square root of –1. The complex eigen value ν can be calculated by the following relation

$$\nu(\nu+1) = (k_0 R \delta)^2 \qquad (4)$$

where, $\delta = \left(1.64 - 0.1759 \ln f + 0.01791 (\ln f)^2\right) - i\left(5.49 \dfrac{0.063\, f^{0.64}}{f}\right)$ and $k_0 = \dfrac{2\pi f}{c}$ is the wave number in free space.

The quality factor Q of the resonant cavity may also be calculated. It is defined as a ratio between the stored energy and energy loss per cycle. If we consider only the electrically stored energy then the Q is written as [16]

$$Q = \frac{\mathrm{Re}\ \delta}{2\,\mathrm{Im}\,\delta} \qquad (5)$$

When, only the magnetically stored energy is considered, the Q is written as [16]

$$Q = \frac{1}{2\,\mathrm{Re}\,\delta\,\mathrm{Im}\,\delta} \qquad (6)$$

And when we consider both electrically and magnetically stored energy, the Q is written as [16]

$$Q = \frac{1 + (\mathrm{Re}\,\delta)^2}{4\ \mathrm{Re}\ \delta\,\mathrm{Im}\ \delta} \qquad (7)$$

All the three definitions of Q given in eq^n (5), (6) and (7) yield the same result as Re δ approaches to unity but they will differ near the lower resonance frequency of Earth-ionosphere cavity. On earth, the quality factor ranges from 4-6 [17]

SR intensity and global thunderstorm activity are minimum at night time or early dawn and maximum in the afternoon hours [18]. It is found experimentally that the day-to-day variation of the resonance frequency coincides with the variation of the lower ionospheric conductivity [19]. Interest in SR measurements was died out completely during the 1980. However, the situation changed when Williams in 1992 demonstrated a clear annual correlation over a six- year span between the variations of the first SR mode intensity (horizontal magnetic field component) recorded at Rhode Island by the Polk group and the tropical temperature [20].

2. Previous Observations of Schumann Resonances:

Observations of Schumann Resonances are a simple and inexpensive method for continuously tracking regional and global lightning activity. SR are measured using electromagnetic sensors consists of two horizontal antennas for receiving magnetic fields in the north-south and east-west direction and one vertical antenna for observing the vertical electrical field. These days usually magnetic field is recorded for SR because the measurement of electric field is very error prone. Since the magnetic field signal is of the order of pT (10^{-12} Tesla) therefore induction coils of high permeability as well as several 10000 turns are used for the measurement of magnetic components of the field. SR measurements should be done in isolated rural areas away from industries, power lines and traffic where soil conductivity is well and underlying geology is uniform [17]. The frequencies and amplitude of SR modes vary during some phenomena which change the state of Earth-ionosphere cavity. After setting the theoretical background about the existence of SR in Earth-ionosphere waveguide by Winfried Otto Schumann, the first successful observations of SR was carried out by Balser and Wagner and produced positive evidence of Earth-ionosphere cavity [21,22]. Cannon and Rycroft in 1982 observed the fluctuations of the fundamental and harmonic frequencies of the SR during sudden ionospheric disturbances (SID) [23]. The measurements at the Nagycenk observatory in Hungary displayed the annual and semi-annual changes for the first three SR modes both in frequencies and their respective amplitudes [24]. They described that each mode has its own character and they show distinct daily and seasonal variations. Roldugin et al. [25] observed the variations in the first and second mode of SR frequencies during intense solar X-ray bursts. They found the variation of 0.2 Hz and 0.3 Hz in the first and second mode of SR frequency respectively. Recently, Simões et al. observed signatures of Schumann resonances in the ionosphere using electric field data gathered on the low earth orbiting C/NOFS satellite in the altitude range of 400-850 km [26]. They detected SR during the night when the plasma density below the satellite was considerably reduced. Their observation of SR frequencies were found same as observed on the ground but the amplitudes of the first peak were $\sim 0.25\ \mu V m^{-1} Hz^{-1/2}$ which is about 3 orders of magnitude lower than observed on the ground.

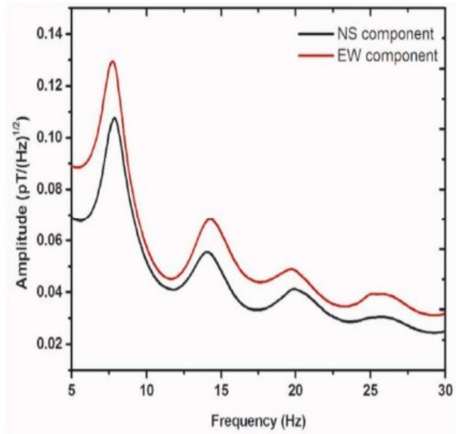

Fig. 1. Amplitude spectra of SR over Maitri, Antarctica [27].

3. Applications of Schumann Resonances:

Schumann Resonances as shown in Fig. 1 are excited by EM radiation below 100 Hz emitted by lightning return strokes and specifically those associated positive strokes with substantial continuing current and charge moment change. The variations of SR spectra can provide us lot of information like global lightning activity, monitoring of global temperature, state of the Earth-ionosphere cavity etc. Some of the applications of SR measurements are given below

3.1. Global thunderstorm/lightning activity:

Lightning in the atmosphere is the main source of electromagnetic radiation in ELF range. Schumann resonances are used to study the daily and seasonal variability of lightning in the cavity. The amplitudes of the peaks in SR spectra are used to calculate the occurrence number as well as magnitude of global lightning discharges. Simultaneously measurements of SR on the other side of the globe provide the same results implying that a single station can be used to track the global lightning activity.

3.2. Tracking upper tropospheric water vapour variations (Monitoring of global temperature):

Change in upper tropospheric water vapour (UTWV) amount is crucial for future global warming because it has a direct impact on Green House effect. Some climate models predict UTWV to increase by 20% for every 1 K increase in surface temperatures [28]. However, monitoring the upper-tropospheric water vapour globally over long timescales is very difficult. Price showed that the upper-tropospheric water-vapour variability and global lightning activity (Schumann resonances) are closely linked [29]. He further described that as the global lightning induces Schumann resonances, monitoring of these resonances from a single location on Earth's surface might provide a convenient method for tracking upper-tropospheric water-vapour variability and hence may contribute to a better understanding of the processes affecting global climate change. Sato observed the anti-phase relation between lightning activity and the upper cloud coverage i.e. spectral power of SR decreases when the amount of the tropical upper cloud coverage increases and vice-versa [30]. Hence, it is inferred that as the amplitudes of SR decreases it may be due to the increased cloud coverage which further reduces the incident flux of solar visible and infrared radiation to Earth. So the heating rate of the ground surface would decrease which further decreases the convection and consequently UTWV decreases.

3.3. Tracking of solar X-rays burst and geomagnetic disturbances:

The Schumann resonance intensity is controlled not only by thunderstorms but also by the solar and geomagnetic activity. It is well known that the ionosphere in Earth's atmosphere is created by the energetic solar radiation. Variation in solar activity changes the ionospheric plasma and affects the characteristics of the global Schumann resonance of the Earth-ionosphere cavity. According to Roldugin et al., X-ray bursts and solar proton events affect the ionosphere in different ways [31]. Growth of the solar X-ray flux enhances the electron density without a significant change of the ionosphere altitude. However, solar protons penetrate deep into the atmosphere and ionize regions lower the normal D region that corresponds to a decrease of the ionosphere altitude. The solar X-ray bursts are usually followed by solar proton events (SPEs). The X-ray activity and SPEs are commonly observed in time of maximum of solar cycle. A 3.5% increase in the first Schumann resonance frequency during a strong X-ray event and a decrement of 1% in the frequency of the first Schumann resonance were observed during the relativistic proton precipitation of 6 November, 1997 [31]. The increments of ~0.2 Hz and ~0.3 Hz in frequency of first and second SR modes respectively were observed during the intensive solar X-ray bursts and its duration coincides with the time interval of the X-ray burst [25]. Nickolaenko et al. in 2011 observed that at the time of a gamma-ray burst of December 27, 2004, all the resonance parameters (peak frequency, amplitude, and Q-factor) diminished [32]. The start of the variations coincided with the arrival of the gamma rays and later on, a trend towards the recovery of the regular resonance structure was observed. In this way, monitoring of the Schumann resonance allows for studying both the Earth-ionosphere cavity and the natural sources of radiation such as solar proton events, solar flares and γ-ray bursts and lightning strokes.

3.4. Monitoring TLEs:

It is well established that TLEs are associated with the energetic cloud-to-ground or intracloud lightning. It has also been found that some SR transients (Q-bursts) are released as the transients luminous events occur especially during red sprites occurrence. SR records can be used to estimate the magnitude of the charge removed from cloud bottom to ground i.e. charge moment change associated to the lightning discharge. The charge moment change is defined as the product of the mean altitude above ground level from which the charge is lowered to ground, and the amount of charge lowered [33]. The charge moment change is the crucial parameter in determining which lightning discharge can produce sprites. Hu et al. [34] analyzed a large number of sprite associated lightning discharges and found that at least 120 C km parent lightning charge moment is required for the initiation of sprites. Further, they reported that the probability of sprite generation for positive lightning with >1000 C km charge moment change in <6 ms is >90%, while the sprite probability for lightning with <600 C km charge moment change in <6 ms is <10%. Hence, charge moment estimation derived from SR data can be useful for the estimation of global occurrence rate of sprites. Since occurrence rate of sprites and other TLEs (only a few per minute) is very small as compared of regular lightning (50-100 flashes per second around the globe) so SR appears to be one of the most convenient and low cost tools for continuous monitoring of TLEs.

It becomes even more important to monitor the TLEs especially red sprites because they have the potential to increase the concentrations of chemical species like NO_x and HO_x in the mesosphere and lower atmosphere and provide a link between tropospheric processes in the thunderstorms and mesospheric processes in the upper atmosphere [35]. Neubert et al. [36] have shown that considering the global occurrence rate of sprites to be 3/minute, the total global production of $NO_x \sim 10^{31}$ molecules per year, which is of the same order as the minimum production of NO_x, N_2O, N_2O_5 and HNO_3 by solar proton events during a quiet year. Peterson et al. [37] estimated global annual NO_x production by sprites to be between 7×10^{23} and 2×10^{28} molecules per second. Recently, measurements by the Superconducting Submillimeter-Wave Limb Emission Sounder (SMILES) satellite instrument indicated an increase in mesospheric HO_2 above sprite-producing thunderstorms [38]. These chemical changes may produce global cooling or heating in the middle atmosphere.

3.5. Short-term Earthquake prediction:

Many researchers found the anomalous behaviour of SR before the happening of earthquakes which clearly indicate that the prediction of earthquakes is possible by measuring SR. Ohta et al. [39] observed the enhancement at the fourth (or the third harmonic) of SR in Japan prior to the earthquakes (one week before the earthquake) in Taiwan. Bhattacharya et al. [40] observed the strong electromagnetic emissions in the ELF range with the help of DEMETER satellite as well as ground based techniques before the Gujarat earthquake (the epicentre was in the remote Rann of Kutch area near the border with Pakistan) that occurred on March 07, 2006. According to Xinyang et al. [41] the SR anomalies in association with an earthquake of magnitude 9.0 on 11 March, 2011 in Japan were reported. The anomalous effect was characterized by an increase in amplitude at the lowest four SR modes beginning at 4 days before the earthquake. Christofilakis et al. [42] observed significant and long lived ELF perturbations in the Schumann Resonance band before and during a shallow mid-magnitude seismic activity in the Greek area (Kalpaki) at very close to seismic epicentre. Florios et al. [43] observed two medium magnitude earthquakes separated by a distance of 230 km occurred within 34 days from each other in Northern Greece. They found the enhancement of SR peaks in the frequency range of 20-25 Hz (with a high maximum at around 21 Hz) before a few hours of the onset of seismic activity.

According to Hayakawa et al. [44], the pre-earthquake seismic activity somehow disturbs the conductivity profile of atmosphere above and in the vicinity of earthquake epicentre. The nonuniformity might appear extend from the ground to the lower ionosphere. This disturbance reflects the ELF radio waves of the SR band (4-40 Hz). As a result, an observer detects two waves: One arrives directly from the field sources (global lightning activity), and the other is the wave reflected by the seismogenic nonuniformity. Interference of these waves causes anomalies in the observed SR spectra. All these events indicate that the ELF measurements (SR) could potentially be used as a useful tool in the forecasting of earthquakes.

4. Lightning, TLEs and SR at other planets:

Giles et al. [45] observed eleven transient bright flashes in Jupiter's atmosphere using the ultraviolet spectrograph instrument on the Juno spacecraft. Their brightness was found to decay exponentially with time, with duration of ~1.4 ms and a source altitude was 260 km above the 1-bar level where majority of Jupiter's lightning forms. Lightning study on Jupitar reveals that most of the lightning flashes occur at near its poles and a flash of Jovian lightning has ten times stronger as compared to lightning on earth with peak rate of four strikes per second. Recently, Pabari and Sana [46] described that the dust devils prevail near the Martian surface during the Southern hemisphere summer. Low atmospheric pressure and arid, windy environment at Mars suggest that dust devils are more susceptible to triboelectric charging in which electric field can reach up to 5-20 kV/m and ultimately lightning is created, giving rise to SR in the cavity. It is found that the observable SR on Mars is primarily dependent on the shape of the dust devils [46]. Hence, SR measurements on Mars can provide us the information about the type of dust devil and ultimately the weather of the planet. Saturn atmosphere was also found with lightning activity by continuous observations of the radio signatures called SEDs (Saturn Electrostatic Discharges). SEDs were initially detected by the radio instrument on-board Voyager 1 near Saturn and by the Cassini RPWS (Radio and Plasma Wave Science) instrument around Saturn Orbit Insertion [47,48]. SED signals are at least 10^4 times stronger than the radio signals of terrestrial lightning in the frequency range of a few MHz [48]. Storm size, storm duration and illuminated cloud region at Saturn are even larger than Jupiter. Titan the Saturn's moon may also be the candidate of having lightning discharges or Schuman resonances as described by various authors.

Hence with the help of lightning activity/SR, we can determine the weather and electromagnetic environment of any planet.

5. Schumann Resonances and Life on Earth:

According to Nikola Tesla, our entire biological system the brain and the earth itself work on the same frequency (between 6 and 8 Hz). If we can control that resonant system electronically, we can directly control the entire mental system of human kind. Absence or a large variation in ELF may produce various side effects on health of human beings. The effects include altered blood pressure and melatonin, increased cancer, reproductive, cardiac and neurological disease and even death. Many occupational studies have found that exposure to ELF fields between 16.7 Hz and 50/60 Hz significantly reduces melatonin levels. Recently, the positive effects of the ELF radiation produced by lightning have been found on the development of life just similar to the effects of visible radiation on many biological processes. Schumann resonance pulses are thought to calibrate us and enhance our physical and mental well-being. It is possible that these signals act like a natural tuning fork, not just for the biological oscillators of the brain, but for all processes of life. E. Jacobi [49] carried out a research at University of Düsseldorf and showed that the absence of Schumann waves creates mental and physical health problems in the human body. In another research, Professor R. Wever [50] from the Max Planck Institute for Behavioral Physiology in Erling-Andechs began a study where he built an underground bunker that completely screened out magnetic fields. He then had student volunteers live in the bunker for four weeks, where they were hermetically sealed in this environment. Throughout the four weeks, Professor Wever noted that the student's circadian rhythms diverged and that they suffered emotional distress and migraine headaches. Wever then added the Schumann frequency back into the environment and only a brief exposure to 7.8 Hz the volunteers' health became stabilized.

6. Discussion, Conclusion and Future Scope:

Atmospheric discharges in the form of conventional lightning which occur in the tropospheric region and transient luminous events such as red sprites, blue jets and elves which occur at an altitude ranging from top of the thunderstorms to the ionosphere have been observed by the scientific community regularly. Conventional lightning discharges are well studied but transients luminous events are still not studied well and currently it is a hot topic of research among researchers. It is thought that TLEs are associated with conventional lightning but a concrete mechanism is needed which can explain this electromagnetic coupling between troposphere and upper atmosphere. Lightning is a powerful tool for understanding the complexities of other planets or satellites. The spatial distribution of lightning can tell scientists whether it is associated with thunderclouds, hurricanes, or a specific geographic feature like a volcano. How lightning strikes vary over time can also reveal daily or seasonal weather patterns. The lightning associated natural electromagnetic noise known as Schuman resonances has likely existed on the Earth ever since the Earth had an atmosphere and an ionosphere. SR is mainly used in lightning research, but its recent application in earthquake science may bring a new and perspective tool in the field of seismo-electromagnetics. In earthquake prone regions a continuous observation of SR should be done in order to avoid any damage. Many authors reported that sprites and blue jets are sources of ELF waves but how much they contribute to SR is needed to calculate. We are already surrounded by many manmade and natural frequencies. The manmade frequencies are however relatively new and many efforts are made to understand its interaction with biological systems but the influence of natural electromagnetic waves on biological systems is poorly studied, mainly due to the low magnitude of these fields. A rigorous study about the interaction of ELF waves on biological system is needed to understand the various health related issues.

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