

«The Pulse of the Earth» Myth: The Physical Reality of Schumann Resonance

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Submitted: 02 August 2026 Accepted: 10 September 2026 Publication date: 28 September 2026

DOI: 10.70671/mq4r7k59

Abstract: This paper examines the physics of Schumann resonance, the structure of the Earth-ionosphere waveguide, the mechanisms of its excitation by global thunderstorm activity, and its geophysical applications. Using spectrograms and magnetometer data from three European observatories (Cumiana, Italy; Lot-et-Garonne, France; and Sodankylä, Finland), this study analyzes the influence of X-class solar flares and the extreme G5 geomagnetic storm of May 2024 on these standing wave parameters. The hypothesis that sudden ionospheric disturbances (SIDs) cause a positive shift in resonance frequencies of 0.1–0.5 Hz is confirmed by the observational data. These findings hold crucial practical relevance for navigation (GPS/GNSS) accuracy, polar aviation safety, and global meteorological monitoring.

Author keywords: Schumann resonance; G5 geomagnetic storm; ionosphere; D-layer; solar flares; ELF fields; Earth-ionosphere waveguide; Pc1 geomagnetic pulsations

Introduction

This paper investigates the mythology behind the “Pulse of the Earth” through the physics of Schumann resonance (SR). Physically, Schumann resonance is a set of extremely low-frequency (ELF) global electromagnetic wave peaks that propagate and bounce inside the resonant cavity formed between the Earth’s surface and the lower ionosphere.^{1,2} These signals are primarily generated and continuously excited by lightning strikes occurring worldwide.³ The main base (fundamental) frequency is approximately 7.83 Hertz, a value that is often colloquially referred to as the Earth’s “heartbeat” or “pulse”.^{4,5} While this specific frequency has gained significant attention in interdisciplinary and alternative fields, often linked to human brain alpha rhythms, this research aims to deconstruct the esoteric mythology by grounding the phenomenon strictly in geophysical reality.

Physics of the Schumann resonance

Schumann resonance as a phenomenon was first mathematically predicted by the German physicist Winfried Otto Schumann¹ while studying the properties of spherical resonators. He demonstrated that the cavity between the Earth’s surface and the ionosphere acts as a global waveguide, trapping electromagnetic waves from lightning to form standing waves (see Fig. 1). In an idealized model featuring perfectly conductive spheres, the natural frequencies of this

resonator are determined by Eq. (1):

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

where c is the speed of light, R is the radius of the Earth, and n is the harmonic number.¹ For the first fundamental harmonic ($n = 1$), Eq. (1) yields a theoretical frequency of approximately 10.6 Hz. However, due to the finite conductivity of the actual ionosphere, the resonance frequency shifts downward and averages **7.83 Hz**.⁵

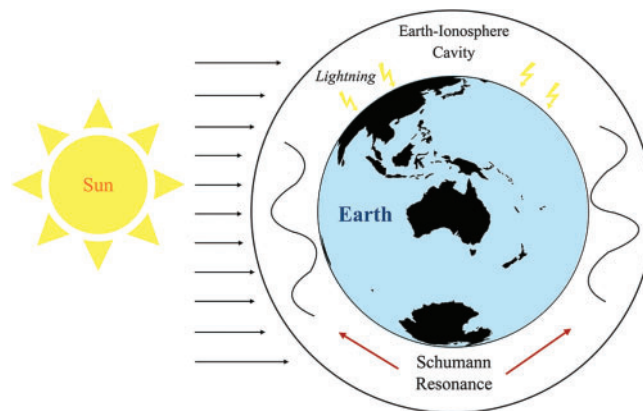


Figure 1. Illustration of the Schumann resonance mechanism in the Earth-ionosphere spherical waveguide

The physical environment facilitating Schumann resonance requires a specific three-layer structure to act as a waveguide for ELF radio waves: the highly conductive Earth’s surface, the upper region of the Earth’s atmosphere (the ionosphere), and the dielectric atmospheric space between them forming the resonant cavity.²

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Consequently, the 7.83-Hertz (Hz) frequency is fundamentally the natural resonant frequency of this specific cavity, not an inherent pulse of the Earth itself. Furthermore, while 7.83 Hz represents the primary and most intense fundamental mode, the waveguide supports higher-order resonant harmonics. Due to increased energy attenuation at higher frequencies, these subsequent harmonics are progressively weaker, typically observed at approximately 14.3 Hz, 20.8 Hz, 27.3 Hz, and 33.8 Hz (see Fig. 2).

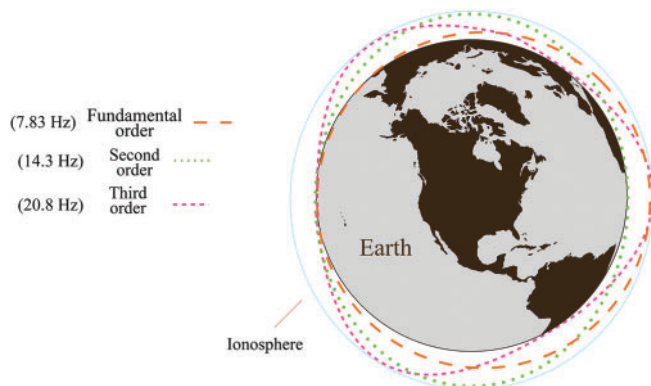


Figure 2. Formation of standing electromagnetic waves in the «Earth-ionosphere» waveguide: the fundamental mode (7.83 Hz), the second harmonic (14.3 Hz), and the third harmonic (20.8 Hz)

The ionosphere and solar flare modulation

The ionosphere constitutes a weakly ionized plasma region in the Earth's upper atmosphere, spanning the mesosphere and thermosphere (see Fig. 3). It is conventionally stratified into three layers based on electron density profiles: the D-layer (starting at approximately 70 km), the E-layer (≈ 100 km), and the F-layer (above 220 km).

A defining characteristic of the ionosphere is the continuous formation of ions and free electrons, driven by the photoionization of neutral atmospheric gases by solar extreme ultraviolet (EUV) and X-ray radiation emitted by the Sun. As established, the highly conductive Earth's surface and the lower boundary of the ionosphere (specifically the D-layer) bound the global resonant cavity. Throughout transient solar events, such as solar flares, sudden bursts of high-energy radiation precipitate significant ionospheric anomalies, thereby deforming the upper boundary of this waveguide and directly altering the resonant frequencies.⁶

The physical mechanism is driven by sudden ionospheric disturbances (SIDs). During a major solar flare, an intense flux of X-rays and hard ultraviolet radiation strikes the Earth's daylit hemisphere. This radiation induces an ultra-intense ionization of neutral gases, causing a sharp increase in free electron density in the lower D-layer. Therefore, the electrical conductivity of the D-layer is substantially

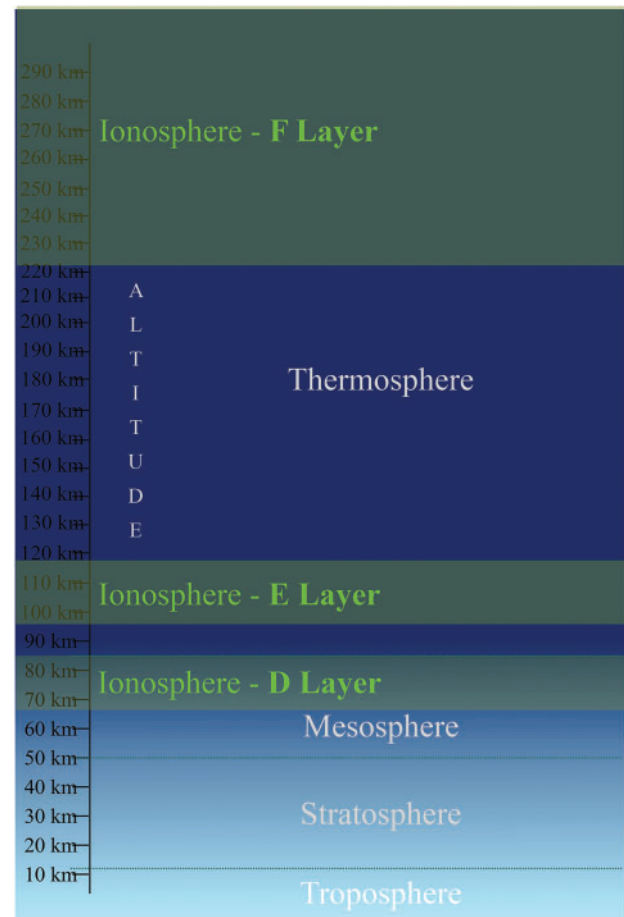


Figure 3. The structural profile of the Earth's atmosphere and the primary electron density layers of the ionosphere

enhanced, and the ionosphere starts reflecting extremely low-frequency (ELF) electromagnetic waves at lower altitudes. The effective upper boundary of the waveguide descends by several kilometers toward the Earth's surface.⁶

According to classical electrodynamics waveguide theory, a reduction in the geometric vertical dimension of a resonant cavity predictably alters its standing wave parameters. Specifically, the descent of the upper boundary shrinks the cavity, which translates to an upward shift of the first (fundamental) Schumann resonance frequency. While non-scientific literature often exaggerates the volatility of the fundamental mode, empirical observations demonstrate that this frequency shift is physically constrained and relatively marginal. Even during extreme X-class solar flares, the fundamental frequency shifts upward by merely 0.1–0.5 Hz, reaching peak values of approximately 7.9–8.3 Hz.⁶

Upon the cessation of the solar flare, recombination processes of charged particles rapidly dominate in the D-layer. The local conductivity gradually reverts to pre-flare levels, the waveguide “ceiling” ascends, and the fundamental SR

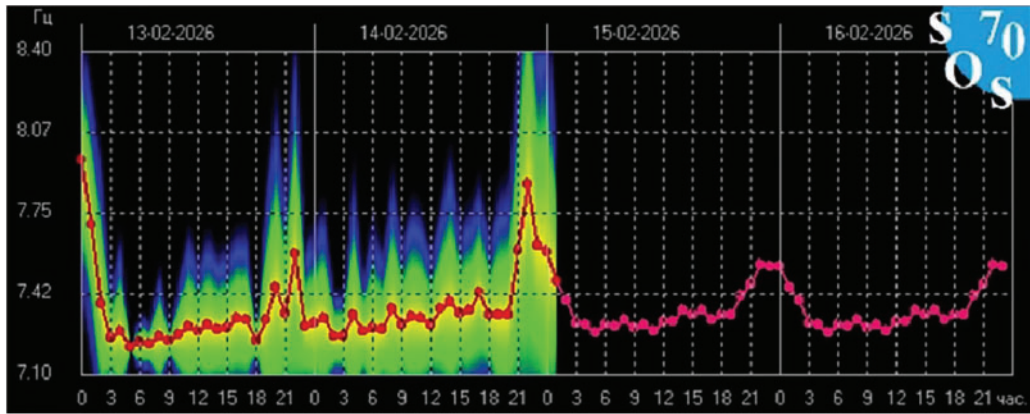


Figure 4. Recorded frequency variations of the fundamental SR mode (7.83 Hz) during the period from February 13, 2026, to February 14, 2026, obtained from the Tomsk State University (TSU) Space Observing System. The dashed line indicates a projected frequency trend for the subsequent 48 hours

Table 1. Nomenclature of the frequency and wavelength bands⁷

Band number	Symbols	Designations	Frequency range (lower limit exclusive, upper limit inclusive)	Corresponding metric subdivision
–1			0.03–0.3 Hz	Gigametric waves
0	TLF	Tremendously low frequency	0.3–3 Hz	Sub-gigametric waves
1	ELF	Extremely low frequency	3–30 Hz	Super-gigametric waves
2	SLF	Super low frequency	30–300 Hz	Megametric waves
3	ULF	Ultra low frequency	300–3000 Hz	Sub-megametric waves
4	VLF	Very low frequency	3–30 kHz	Super-kilometric waves
5	LF	Low frequency	30–300 kHz	Kilometric waves
6	MF	Medium frequency	300–3000 kHz	Hectometric waves
7	HF	High frequency	3–30 MHz	Decametric waves
8	VHF	Very high frequency	30–300 MHz	Metric waves
9	UHF	Ultra high frequency	300–3000 MHz	Decimetric waves
10	SHF	Super high frequency	3–30 GHz	Centimetric waves
11	EHF	Extremely high frequency	30–300 GHz	Millimetric waves
12	THF	Tremendously high frequency	300–3000 GHz	Sub-millimetric waves

frequency returns back to its baseline average of 7.83 Hz. It is crucial to note, however, that despite being a «baseline», the 7.83-Hz frequency is never perfectly static; it fluctuates continuously within narrow limits driven by diurnal and seasonal atmospheric dynamics⁵ (see Fig. 4).

Excitation sources and monitoring observatories

Lightning discharges act as the primary excitation source of electromagnetic waves that resonate within the Earth-ionosphere waveguide cavity. In addition to the visible electromagnetic waves, lightning emits a broad spectrum of

electromagnetic radiation, most notably in the extremely low-frequency (ELF) band. According to the International Telecommunication Union,⁷ these relevant ELF waves operate at frequencies ranging primarily from 3 Hz to 30 Hz (see Table 1), corresponding to massive wavelengths between 10,000 km and 100,000 km.

Research Methods and Outcomes

To investigate the dynamics of geomagnetic activity and the subsequent Schumann resonance parameters during the

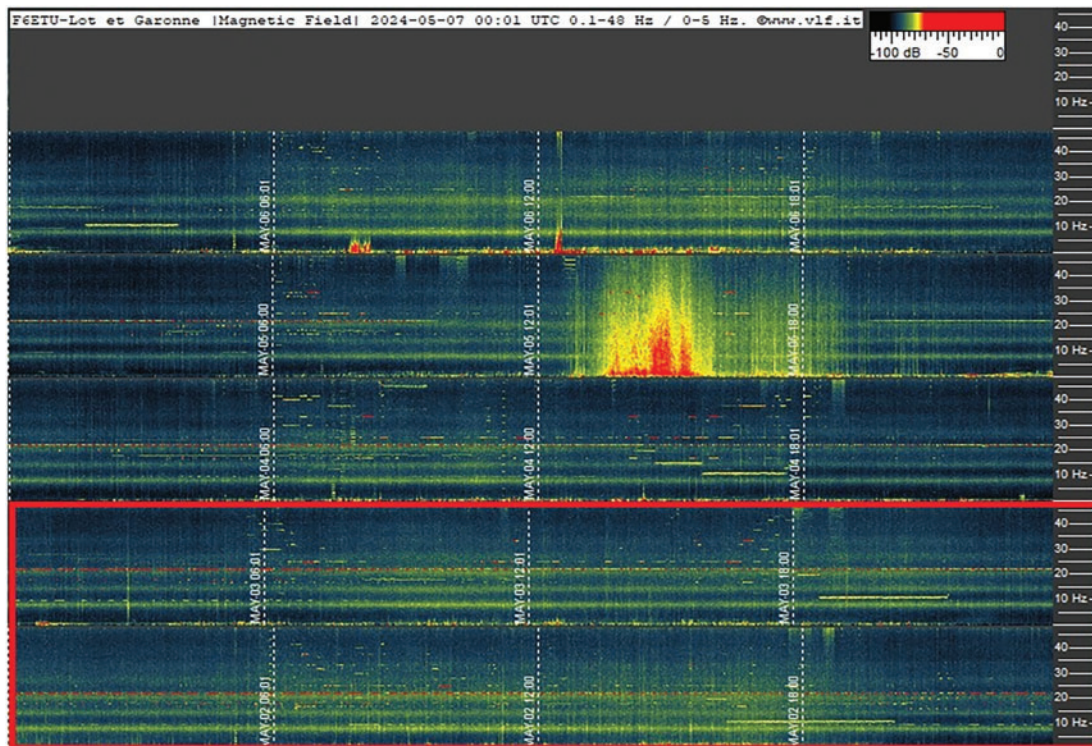


Figure 5. Magnetic field spectrogram for the period from May 2, 2024, to May 6, 2024, recorded at the Lot-et-Garonne station. A red box highlights the stable pre-storm interval under study⁹

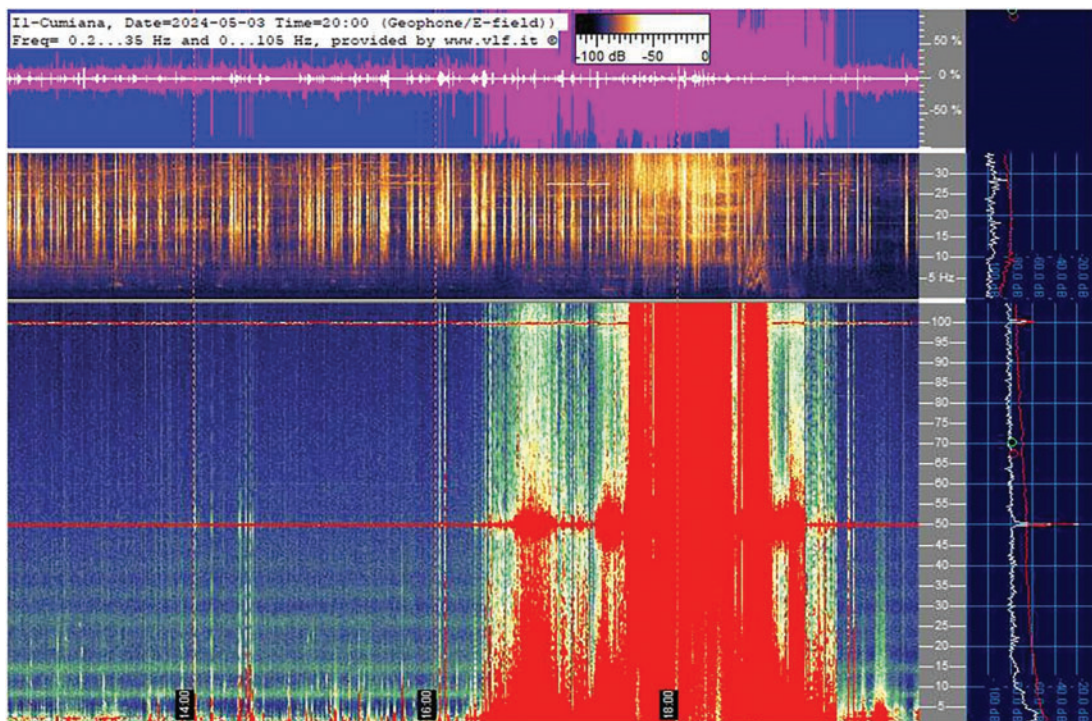


Figure 6. Spectrogram of the electric field recorded by the Marconi antenna at the Cumiana station on May 3, 2024, showing a vertical spike indicative of local weather interference¹⁰

extreme G5-class geomagnetic storm of May 2024,⁸ observational data were acquired from three specialized European stations: Cumiana (Italy), Lot-et-Garonne (France), and Sodankylä Geophysical Observatory (Finland).

The geographical distribution of these observatories allows for a comprehensive latitudinal analysis. Due to its high-latitude location near the auroral zone, the Sodankylä Observatory in Finland utilizes a pulsed magnetometer to

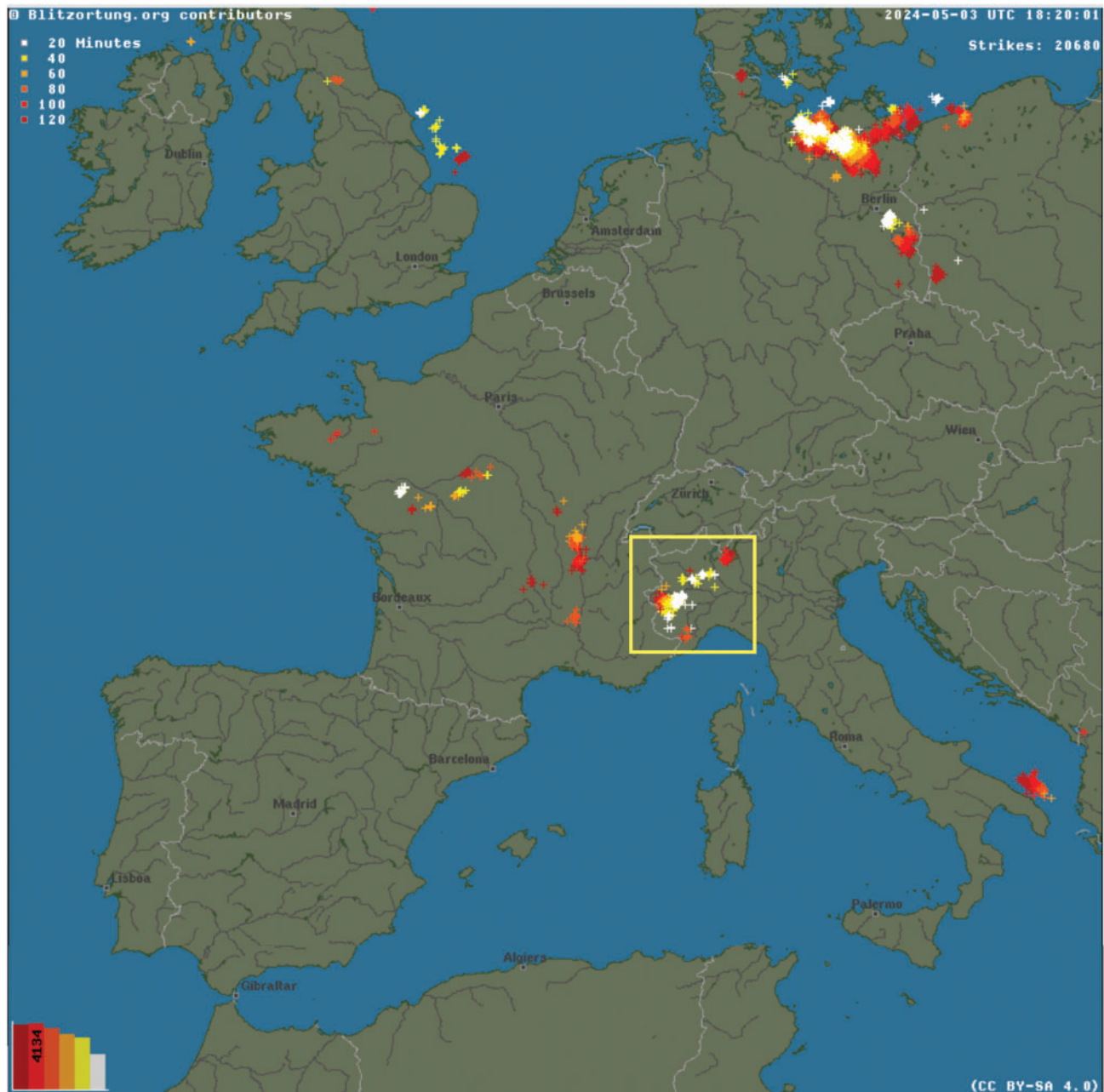


Figure 7. Map of thunderstorm activity across Europe on May 3, 2024 (18:20 UTC). The area in northwestern Italy near the Cumiana station is highlighted in yellow¹¹

detect the subtlest fluctuations in the geomagnetic field, where auroral and geomagnetic disturbances are most intense. The mid-latitude Italian station at Cumiana records high-fidelity data using a vertical low-frequency Marconi antenna, enabling precise monitoring of the Earth's electric field dynamics. The Lot-et-Garonne (LOT) Observatory in France captures broad magnetic field variations using an ICS101 induction coil.

The primary methodology in this section involves a comparative chronological analysis of spectrograms and frequency graphs spanning from May 2 to May 11, 2024. This timeframe coincided with a series of powerful X-class solar flares and the resulting G5 geomagnetic storm. A key

objective of this analysis is to empirically test the hypothesis that during extreme solar flares, the Schumann resonance frequency undergoes an upward shift of 0.1–0.5 Hz due to sudden ionospheric disturbances (SID), without returning to its natural minimum during quiet baseline periods.

Analysis of geomagnetic activity during the G5-class geomagnetic storm (May 2024)

Period I: May 2–3, 2024 (Pre-Storm Baseline)

Throughout this initial period, data from the LOT station indicated that the regional magnetic field remained largely stable (see Fig. 5). However, an analysis of the electric field spectrogram from the Italian Cumiana station revealed a

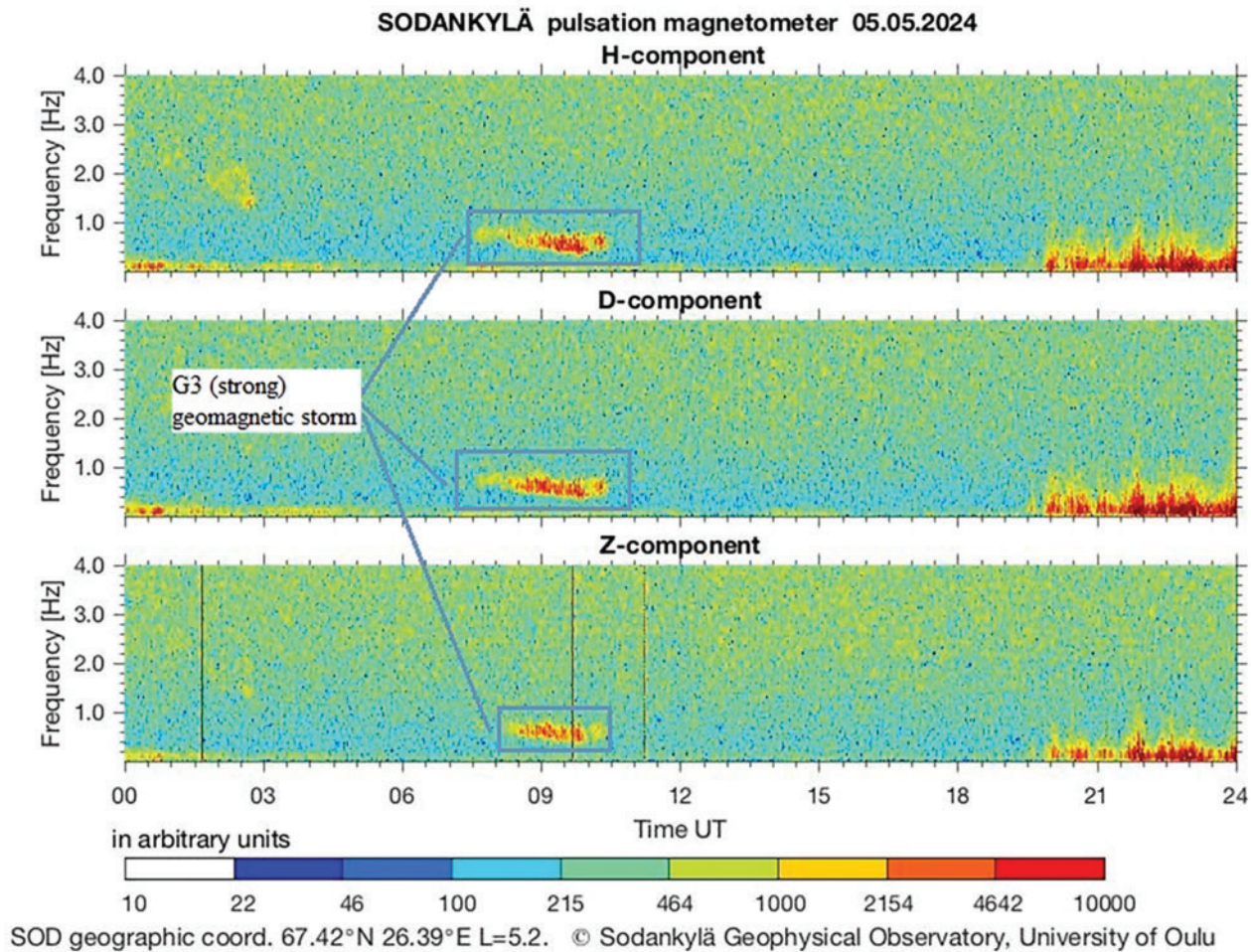


Figure 8. Spectrogram of geomagnetic pulsations recorded by a magnetometer at the Sodankylä station in Finland (May 5, 2024). The characteristic «pearl» structures indicate continuous Type 1 (Pc1) pulsations, preceding a G3 geomagnetic storm^{12,13}

strong vertical anomaly (see Fig. 6). This intense broadband spike indicates that the signal was of tropospheric origin, caused by localized atmospheric precipitation and lightning, rather than by global geomagnetic processes. Independent meteorological data confirmed significant thunderstorm activity directly over the observatory during this exact period (see Fig. 7).

Period II: May 5, 2024 (Initial Solar Flares and Pc1 Pulsations)

A transition into an active geomagnetic state was observed on May 5, 2024. In contrast to the local electric field surge on May 3, 2024, the spectrogram from the Sodankylä Observatory in Finland displayed distinct structural patterns resembling “pearls” (see Fig. 8). These “pearl-like” features on dynamic spectrograms serve as classical identifying markers for Type I (pc1) geomagnetic field pulsations. A specific Pc1 event was triggered by a series of solar emissions (two X-class flares and at least seven M-class flares) on May 5, 2024, originating from active region AR 3663 due to X-ray and ultraviolet radiation, culminating in a G3 (strong) geomagnetic storm. Concurrently, data from the LOT station in France exhibited an unstable magnetic state

characterized by broadband noise, which coincided with local convective atmospheric precipitation (a thunderstorm) superimposing electromagnetic interference onto the sensor data (see Fig. 9).

Simultaneously, the Cumiana station recorded a definitive shift in the second harmonic of the Schumann resonance (see Fig. 10). Under undisturbed conditions, the second harmonic exhibits a wide oscillation range (from 12 Hz to 14.5 Hz). However, on May 5, as a result of two powerful solar flares, the amplitude decreased noticeably, and the frequency floor did not drop below 14 Hz. Instead, the baseline frequency rose by approximately 0.1–0.5 Hz, providing direct empirical confirmation of the hypothesis regarding SID-induced cavity compression.

Period III: May 10–11, 2024 (The G5 Extreme Geomagnetic Storm)

On May 10, 2024, at approximately 17:15 UTC, all three stations recorded the sudden, violent onset of a geomagnetic storm triggered by the arrival of a complex series of coronal mass ejections (CMEs) (see Fig. 11). The disturbances persisted intensely through May 11, 2024. This event was officially classified as a G5 (extreme) geomagnetic storm,

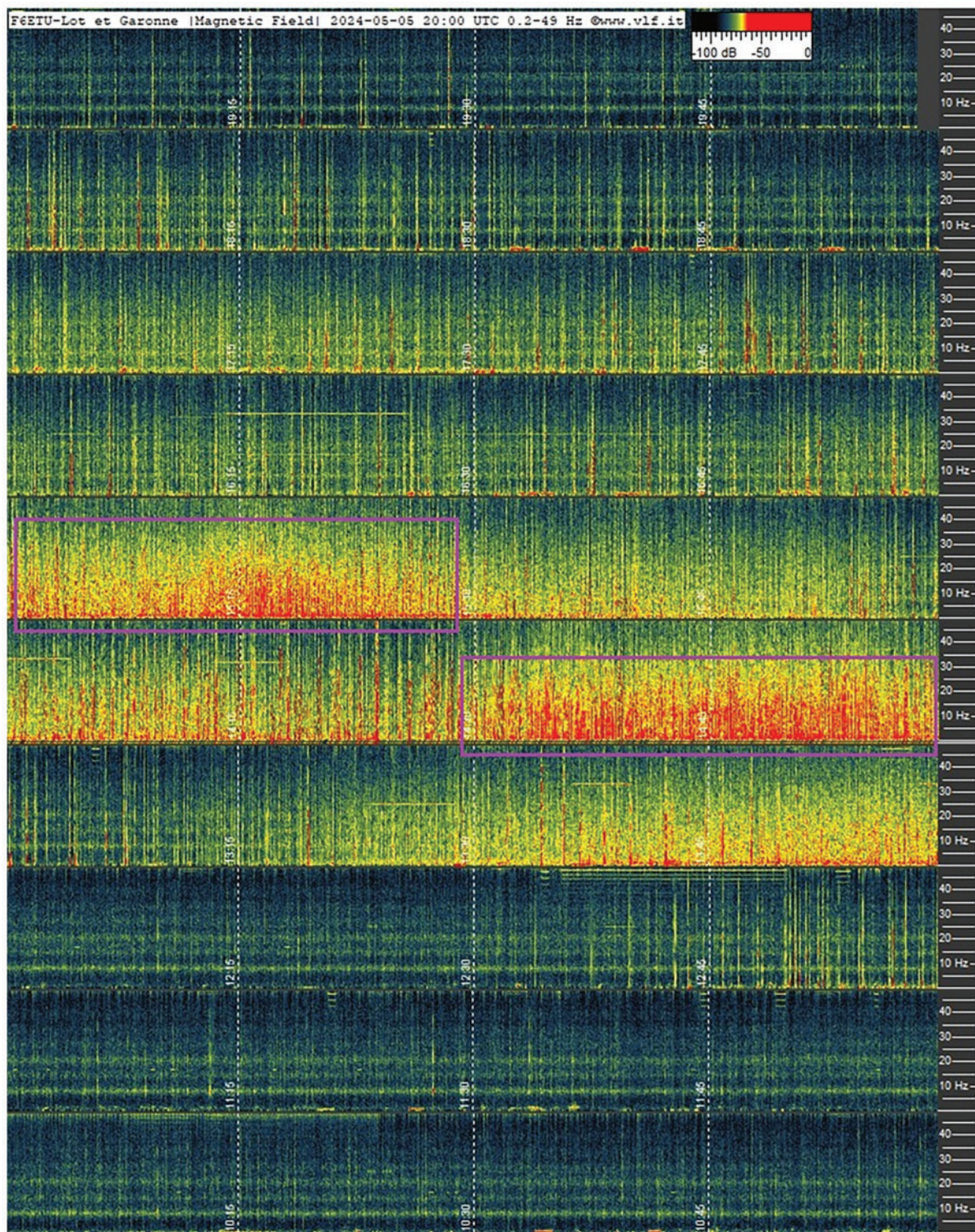


Figure 9. Magnetic field spectrogram for May 5, 2024 (Lot-et-Garonne station). The peak of the local thunderstorm interference is highlighted in purple⁹

marking the first time a solar event of this magnitude had impacted Earth in over 20 years.

Results of the analysis

The hypothesis that severe solar flares affect the Schumann resonance frequency by causing a positive shift of

0.1–0.5 Hz is unequivocally supported by the data collected during this G5 event. This sustained upward trend is clearly visible in the data plotted by the Italian observatory in Cumiana (see Fig. 12). The intense X-ray and EUV radiation caused profound sudden ionospheric disturbances (SIDs), lowering the effective height of the Earth-ionosphere waveguide. As a result, the combination of bright auroral

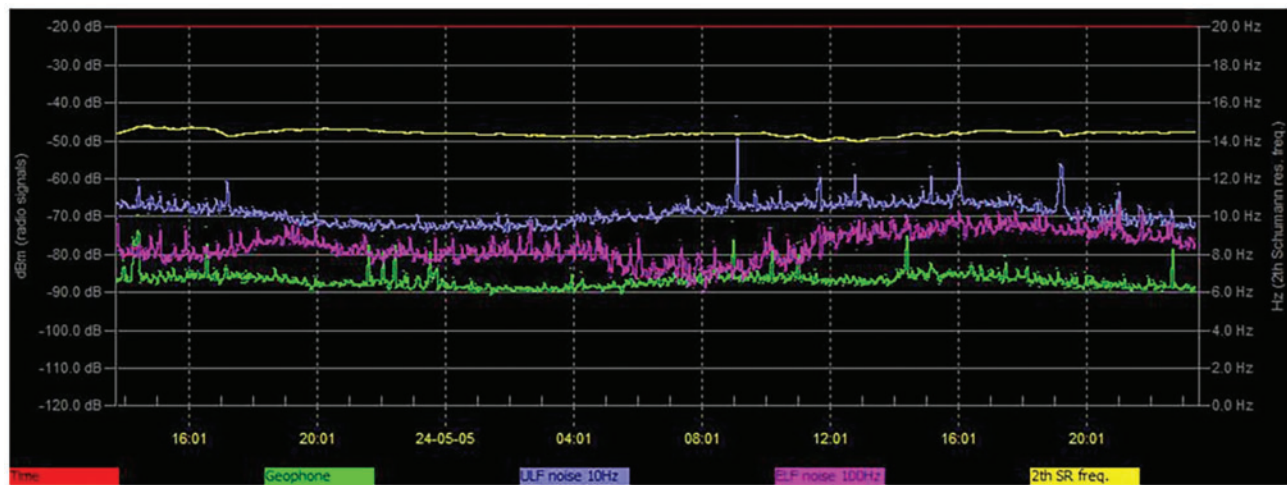


Figure 10. Graph showing the variation in the second Schumann resonance harmonic (yellow line) recorded at the Cumiana station on May 5, 2024¹⁰

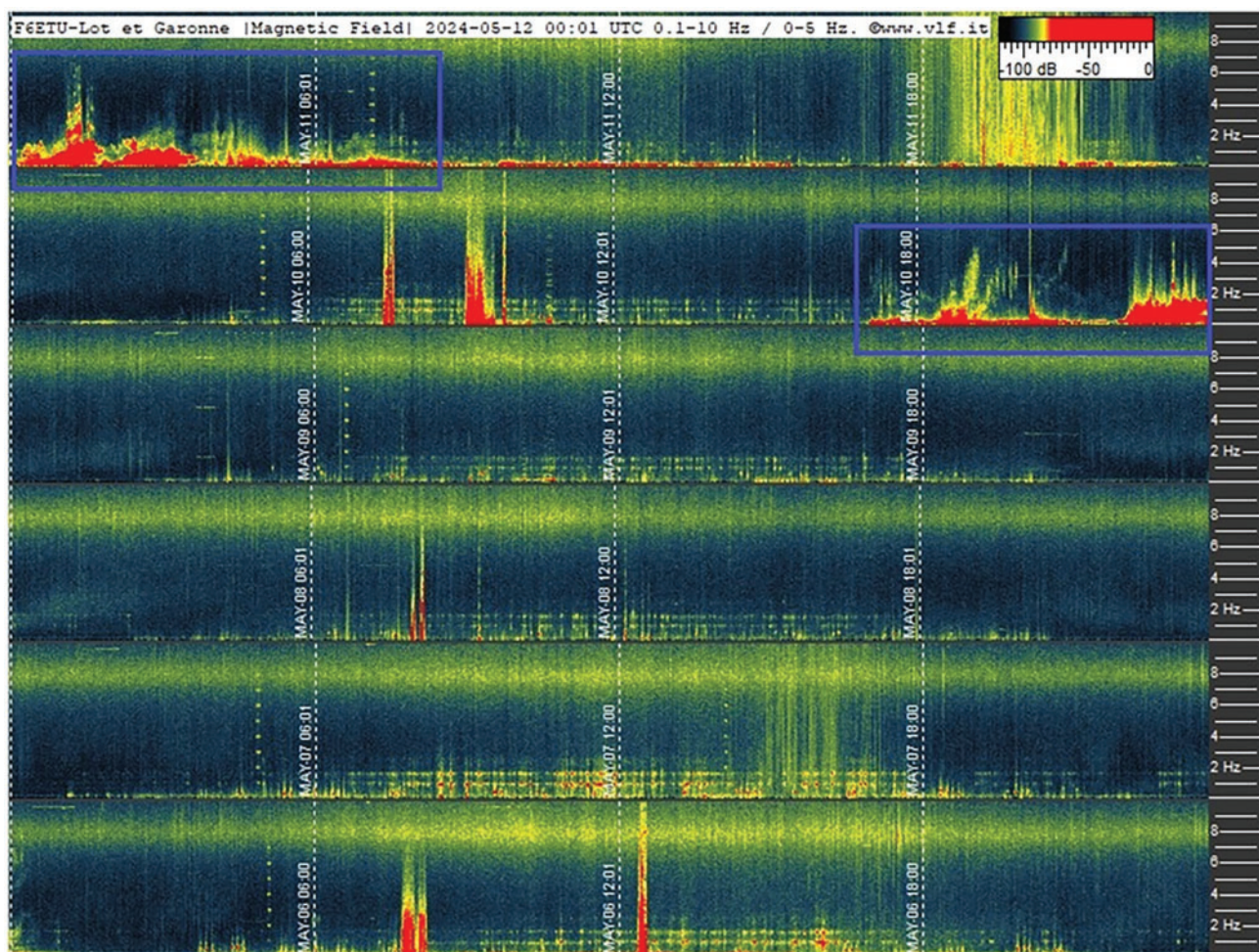


Figure 11. Magnetic field spectrogram from May 6 to May 11, 2024 (Lot-et-Garonne station). The broadband disruptions highlighted in blue (May 10–11) indicate the G5 extreme geomagnetic activity⁹

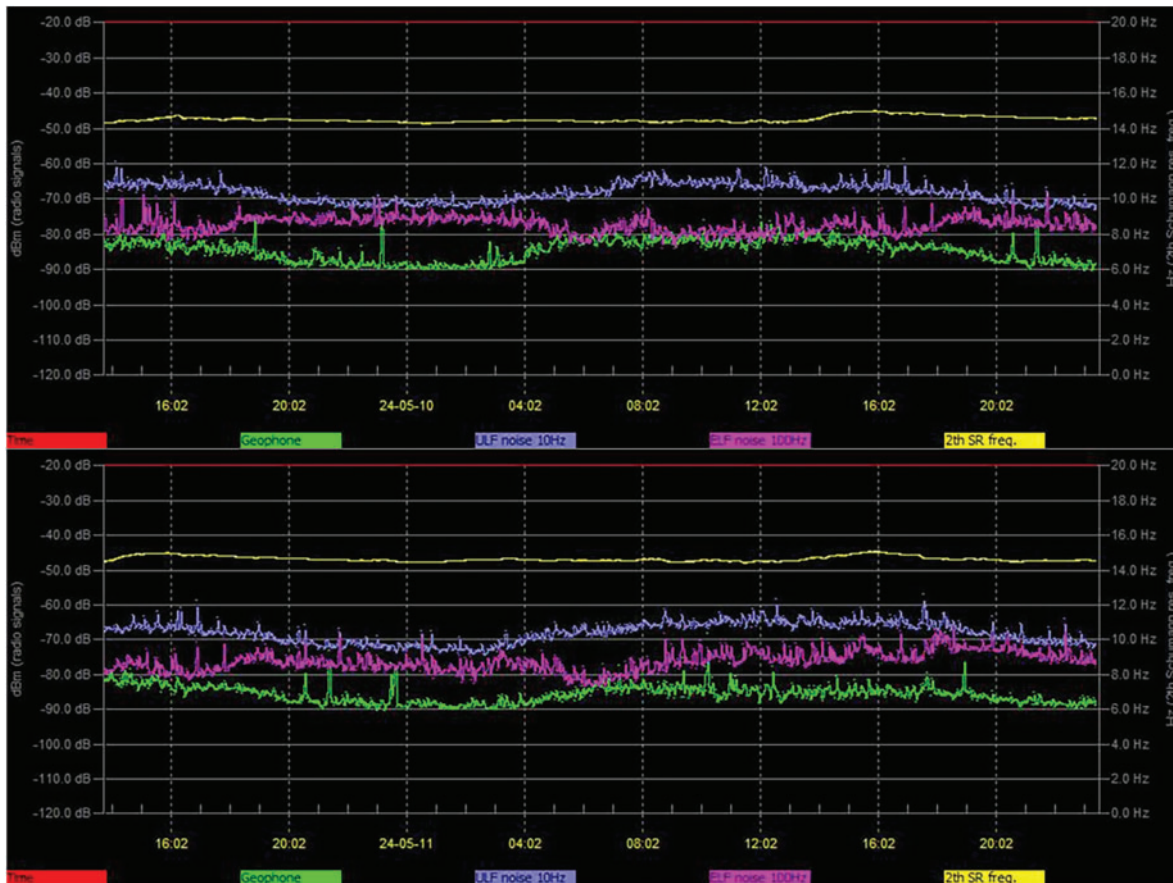


Figure 12. Graph showing the sustained positive shift in the second Schumann resonance frequency (yellow line) at the Cumiana station during the G5 storm from May 10 to May 11, 2024¹⁰

breakups, powerful pulsed currents in the ionosphere, and the compressed resonant cavity directly contributed to the observed upward modulation of the Schumann resonance frequencies.

Conclusion

This study comprehensively examined the behavior of the Earth's electric and magnetic fields from May 2 to May 11, 2024, a period that coincided with a series of extremely powerful X-class solar flares and the resulting G5 and G3 superstorms. The empirical analysis of data from multiple European observatories confirmed the hypothesis: during extreme solar flares, the Schumann resonance frequency consistently experiences a positive shift of 0.1–0.5 Hz and does not drop to its natural minimum throughout the entire period of the geomagnetic storm.

Consequently, an in-depth understanding and continuous monitoring of Schumann resonances provide benefits for fundamental geophysics and the protection of global infrastructure. The practical applications of this research can be summarized as follows:

1. *Accuracy of the Satellite Navigation:* Because the Schumann resonance is a highly sensitive indicator of the state of the ionosphere's D-layer, continuous monitoring of its parameters allows for real-time assessment of ionospheric

ionization during sudden ionospheric disturbances (SIDs). This capability makes it possible to promptly update global models of ionospheric delays, thereby reducing positioning errors in satellite navigation systems (GPS/GNSS) during periods of intense geomagnetic disturbances.

2. *Aviation Safety on Polar Routes:* Commercial aviation, particularly flights using polar routes (e.g., orthodromic paths from New York to Seoul traversing high northern latitudes), relies heavily on stable high-frequency radio communication. Understanding ionospheric behavior and tracking resonance shifts during solar flares provides critical data for air traffic controllers. This allows for the prompt rerouting of aircraft to lower latitudes, steering passengers and crew away from increased radiation exposure and communication blackouts at high altitudes.

3. *Climate and Meteorological Tracking:* Monitoring global thunderstorm activity provides deep insight into how the ionosphere reacts to solar forcing. By accurately calibrating Schumann resonance amplitudes, scientists can robustly estimate the total intensity of lightning discharges on Earth. This enables meteorologists to continuously monitor global thunderstorm activity, which serves as a crucial proxy variable for tracking long-term global climate change processes and atmospheric thermodynamics.

Acknowledgements

I sincerely express my deepest gratitude to Renato Romero (www.vlf.it, OpenLab), Jean Marie Briussel (F6ETU), and Michel Brune (F5WK) for their invaluable assistance in providing scientific data and spectrograms from European monitoring stations (observatories) for my research. Special thanks are extended to Renato Romero for his insightful feedback, expert guidance on ELF monitoring equipment, and literature recommendations during the preparation of this manuscript.

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About the Author



Sofia Sokol is a recent high school graduate with a strong interest in space weather, atmospheric electrodynamics, and planetary sciences. Driven by a deep curiosity about how solar activity shapes the Earth's environment, she independently gathered and analyzed empirical data from international observatories in Italy, France, and Finland for this research. Inspired by the extreme geomagnetic events of May 2024, she is determined to pursue a degree and a lifelong career in geophysics, where she plans to continue exploring the intricate connections between the Sun and Earth's electromagnetic fields.