Eclipse of reason: debunking speculative anticipatory behavior in trees

[1*]Ariel Novoplansky and [2]Hezi Yizhaq

1. Mitrani Department of Desert Ecology, The Swiss Institute for Dryland Environmental and Energy Research, Blaustein Institutes for Desert Research, Ben Gurion University of the Negev, Sede Boqer Campus 8499000, Israel.

2. Alexandre Yersin Department of Environmental Physics, The Swiss Institute for Dryland Environmental and Energy Research, Blaustein Institutes for Desert Research, Ben Gurion University of the Negev, Sede Boqer Campus 8499000, Israel.

*Corresponding author: anovopla@bgu.ac.il

Summary

Advancing plant behaviour research requires adherence to robust experimental designs, the formulation of alternative falsifiable hypotheses, sufficient replication, and stringent controls. These tenets safeguard the field from slipping into pseudoscience. A recent study by Chiolerio et al. (2025) claims that *Picea abies* trees collectively anticipate solar eclipses via electrome-based signalling. Despite widespread media attention, these claims rest on speculative interpretations and weak evolutionary assumptions, warranting critical scrutiny. We systematically evaluate the study's core premises, demonstrating the absence of causal link between the reported electrical activity in the studied trees and the impending solar eclipse event, the absence of reliable environmental cues, and the implausibility of adaptive benefits for such supposed anticipatory behaviour. Instead, we demonstrate that the elevated electrical activity of the trees prior to the solar eclipse can be more parsimoniously attributed to weather-induced stimuli, such as rapid temperature shifts and nearby lightning strikes. Moreover, the proposed mechanisms of inter-tree communication and gravitational memory in the trees lack empirical support and theoretical grounding. The case serves as a cautionary example where enticing narratives overshadow the essential standards of scientific rigor, emphasizing the necessity for critical appraisal and methodological robustness in advancing the field of plant behaviour.

key words: anticipatory responses, forest, *Picea abies*, plant behavior, plant communication, plant electrome, solar eclipse.

"These matters being very extraordinary, will require a very extraordinary proof."

— Benjamin Bayly, *An Essay on Inspiration* (1708)

Introduction

In a recent paper, Chiolerio et al. (2025) claimed to demonstrate that *Picea abies* trees are able to actively and collectively synchronize anticipatory responses to forthcoming solar eclipses. The study garnered widespread attention in leading news and popular-science media, with few doubts about its validity and rigor (but see Simms 2025). Here, we critically evaluate the study's claims, demonstrating that it rests on questionable evolutionary assumptions, insufficient data, and unsubstantiated inferences. We then propose a more mundane parsimonious alternative explanation for the observed phenomena and discuss the potentially destructive implications of empirically unsupported scientific hyperbole.

Plants can perceive and integrate a wide variety of signals and cues not only to respond to past and current environmental conditions but also to improve their readiness for anticipated growth conditions, challenges and opportunities (Novoplansky 2015; Aphalo and Sardas 2022). For example, in response to slight changes in light levels and spectral composition, plants can anticipate impending light competition long before experiencing meaningful photosynthetic shade from their neighbours (Ballare and Pierik 2017). Similarly, sensing minute changes in belowground conditions or semiometabolites, plants are able to respond pre-emptively to imminent nutrient deficits (Zhang and Forde 1998), drought (Passioura 1988), and salinity (Ackerson and Youngner 1975), among others, often relying on relevant information received from neighbouring plants (Ballare and Pierik 2017; Novoplansky 2016; Karban 2021). However, pre-emptive responses are only expected to be selected for when the anticipated conditions are expected to affect fitness, and where there exists a sufficiently tight correlation between the perceived information and the respective anticipated conditions (Novoplansky et al. 2016, 2024).

What is the anticipated challenge?

Solar eclipses, especially total eclipses, may present diurnal organisms with transient functional challenges (Economou et al. 2008). To the extent they decrease available sunlight, solar eclipses may reduce photosynthesis and transpiration rates, increase humidity and lower canopy temperature and sap flow rates; however, these changes have no adverse effects on long-term plant gas exchange and performance (Heberle 2001). Accordingly, the hypothesis that plants can anticipate the effects of solar eclipses warrants scrutiny based on the specific changes caused by each eclipse event, and a clear evaluation of the potential benefits and costs of anticipatory responses to their effects. For example, can the effects of an impending eclipse be predicted based on previous events? Can plants anticipate and plastically prime for the expected changes? To what extent light obstruction by the solar eclipse is meaningful at variable sunlight levels and under various unrelated stresses? The studied case refers to a partial solar eclipse from the Saros 124 series, which had a maximum magnitude (the fraction of the Sun's diameter covered by the Moon at maximum eclipse) of 0.8623, sun obscuration (the fraction of the Sun's visible disk covered by the Moon) of 0.82075, and a total duration of two hours (Espenak and Meeus 2006). At the study site, the magnitude was 0.325 with maximum sun obscuration of 0.211, which resulted in an average sunlight reduction of only 10.5% throughout the duration of the eclipse (calculated based on Möllmann and Vollmer 2006). A study on photosynthetic responses of Picea *abies* trees to variable light intensity demonstrated that even during the eclipse maximum, sunlight levels at the study site (Chiolerio et al. 2025, Fig. S8D) were well beyond the light saturation point of these trees (Marek et al. 1997). Accordingly, such a minor and ephemeral reduction in sunlight is unlikely to be functionally meaningful for spruce trees at the study location, which is characterized by frequent and rapidly changing cloud cover (Desiato et al. 2005), rapid temperature fluctuations, strong wind gusts, and other environmental fluctuations.

What is the functional significance of the plant electrome?

The fundamental premise of the study was that the measured electrome patterns of the studied spruce trees reflected adaptive responses to the solar eclipse. The plant electrome represents the full spectrum of electrical phenomena within and around the plant (de Toledo et al. 2019; Kozlova et al., 2025). It includes bioelectrical signals involved in the communication of and responses to myriad endogenous and environmental stimuli, *regardless of their adaptive value*. Some electrical activities could reflect non-functional noise, external disturbances, or passive phenomena, which have little to do with active responsiveness, let alone adaptive behavior. In fact, by their mere capacity to retain ionic media and conduct electric currents, even dead plants or plant tissues exhibit elaborate electric phenomena (Chiolerio et al. 2022; 2025; Ghildiyal et al. 2025). To demonstrate the functionality and adaptiveness of electrome phenomena, one would need to perform rigorous experiments in which the correlations and functional connectedness between specific repeatable electrome patterns and adaptive responses to specific challenges are clearly demonstrated (e.g. Costa et al., 2023; Simmi et al., 2023; de Toledo et al., 2024), but unfortunately none of that was done in the current study.

Can past solar eclipses inform trees about future ones?

The authors hypothesized that older trees could have anticipated the October 25, 2022 eclipse based on experiences of specific patterns of lunisolar gravitational forces of previous Saros 124 events (Chiolerio et al. 2025). The first Saros 124 solar eclipse occurred on March 6, 1049, and the last will be on May 11, 2347, with a total of 73 events. It occurs every 18 years, 11 days and 8 hours, and thus even the older, more responsive 70-year-old trees mentioned in Chiolerio et al. (2025), would have only lived through three previous

Saros 124 eclipses in 1968, 1986, and 2004 (Fig. S1). Critically, although Saros 124 eclipses occur at periodic intervals, their paths, magnitudes and durations change with each event (Fig. S1), rendering past eclipses uninformative for later ones at any given geolocation. For example, while the path of the 2004 eclipse was over Eastern Asia and the Atlantic Ocean, the 2022 event was over Europe, Africa, and Western Asia, and the 2040 eclipse will be over North and Central America (Fig. S1). Accordingly, even if we assume that spruce trees can recall the gravitational signature associated with past solar eclipses, such recollections would hold no ecological relevance to future solar eclipses. From the standpoint of a given tree in particular geolocation, neither Saros 124 nor any of other 38 – 41 Saros series active at any given time will occur over the same location more than once (NASA eclipse catalogue) , so in spite of experiencing a solar eclipse every 2-4 years, specific trees cannot infer the timing, duration or magnitude of impending solar eclipses based on previous eclipse events. Furthermore, a closer examination of the combined gravitational effects of the moon and the sun shows extremely similar values, with differences seven orders of magnitude smaller than *g* (the gravitational acceleration on Earth), between solar eclipse and new moon events, and between these syzygies and 14 hours prior to them (Squires 2001). Such small differences in *g* are well below the sensory threshold of plants, with minimal responsiveness thresholds of 10^{-3} - 10^{-4} *g* for roots and 10^{-2} - 10^{-3} *g* for shoots (Palme et al. 2018). Accordingly, trees are not expected to rely on lunisolar gravitational effects to anticipate solar eclipses.

Do spruce trees intercommunicate?

The authors claimed that their findings supported the hypothesis that older spruce trees not only presented stronger anticipatory responses to the approaching solar eclipse, but they also shared this information with their younger conspecifics, fostering collective synchronized responses to the impending solar eclipse (Chiolerio et al. 2025). Plants have been readily demonstrated to exchange adaptive information with their neighbours (Karban 2021), relying on various communication channels and modalities, such as intraclonal signalling (Gómez et al. 2007), interplant root grafting (Graham and Bormann 1966), common mycorrhizal networks (Rillig et al. 2025, but see Karst et al. 2023, and Henriksson et al. 2023), volatile organic compounds (Ninkovic et al. 2021) and root exudates (Wang et al. 2021). In some cases, interplant communication was demonstrated to increase synchrony in e.g. defensive responses to herbivory (Markovic et al. 2019), drought (Falik et al. 2023), and flowering timing (Falik et al. 2014). *Picea abies* is known to readily form and sustain natural root grafts (anastomoses) both between roots of the same individual and those of neighboring individuals (Gebauer and Martinková 2005), even with different species (Graham and Bormann 1966). Although rare, *Picea abies* can also propagate asexually by ‘layering’ - the rooting of lateral branches still connected to their parent tree.

Such connections may facilitate resource sharing between mother and daughter trees for decades and enhance their survival and competitive ability in harsh environments (Šenfeldr et al. 2016). While these modes of integration can facilitate resource and information sharing between neighbouring trees over relatively short distances, it is conceivable that inter-tree root grafts foster much longer-range communication amongst more distant trees via relay communication (Falik et al. 2024). However, synchronous responsiveness to external conditions and cues must not necessarily rely on interplant communication. The study does not present sufficient information that could help discern whether the observed synchrony in the behaviour of neighbouring trees was caused by externally induced or communicated stimuli (Fig. 1). As the trees studied grew in the same general location (with 'sites' located 10 - 30 m apart (Alessandro Chiolerio, personal communication), their synchronous responses could have more parsimoniously resulted from simultaneous exposure to the same external conditions and stimuli regardless of the involvement of inter-tree communication (Fig. 1A). Differentiating between these scenarios would require additional observations and experiments in which various modes of inter-tree communication would be manipulated and tested (e.g. Falik et al. 2011; Song et al. 2014). Without delving into detailed theoretical analyses, and although it may serve as a general metaphor, we see no specific advantages in invoking quantum field theory or entanglement in modelling the response of the studied trees to ambient stimuli (Chiolerio et al. 2025).

What elicited the heightened pre-eclipse electrical activity?

The authors attributed the sharp increase in electrical activity, which began ca. 14 h before the solar eclipse, to an anticipatory response of the trees to the impending event. However, studying the ambient conditions at the study site revealed that on the night prior to the solar eclipse (October 24, 2022), there was a significant drop in temperatures and a notable rain event peaking ca. 14h before the solar eclipse (Chiolerio et al. 2025; Fig. S8), which could have triggered the observed increase in the trees' electrical activity. To better assess the potential involvement of weather conditions on the observed electrome patterns, we further analysed the spatiotemporal distribution of all lightning strikes within 200 km of the study site during a 96-hour period beginning at 00:00 on October 22, 2022, based on data from the World Wide Lightning Location Network (Earth and Space Sciences, University of Washington). A total of 664 lightning strikes occurred from October 22 to 25, 2022 (none on October 23) (Fig. 2). Of these, 20 occurred within 45 Km of the study site, 18 of which occurred during the 14-hour time slot prior to eclipse. Notably, all three lightning strikes within 10 km of the study site occurred during the same 14-hour time slot (Fig. 2). Lightning strikes have far-reaching electromagnetic effects at wide frequency ranges (Simões 2012), known to elicit substantial physiological responses in plants, even at their lowest energetic ranges (extremely low frequency; 3 - to 30 Hz (ELF) and Schumann resonances, e.g. Grinberg et al. 2024). Accordingly, a compelling hypothesis emerges, proposing that the pronounced increase in electrome activity ca. 14 h before the solar eclipse was elicited by the steep change in weather conditions and the nearby lightning strikes. The observation that older and larger trees at the study location exhibited greater electrical activity than their younger and smaller neighbours supports the idea that trees act as electromagnetic antennae (Ikrath et al. 1975), with their reception capacity increasing with physical size (Wu et al. 2024).

Discussion

The ability of plants to anticipate forthcoming challenges and opportunities is well recognized and documented. However, the evolution of anticipatory responses critically depends on the presence of - a) well-defined, predictable and adaptively meaningful challenges, b) reliable cues or signals that precede the said challenges, c) clear adaptive advantages for early pre-emptive responses, and d) a capacity of the responding organism to detect and properly respond to these challenges in an efficient and timely manner.

Despite their reliance on merely two older and one younger living trees and five tree stumps, at a single forest location during one eclipse event, Chiolerio et al. (2025) presented far-reaching claims regarding the ability of spruce trees to anticipate solar eclipses. However, careful examination of their findings and claims demonstrates that none of the above-mentioned stipulations have been fulfilled for the studied system (Table 1). Specifically, the supposedly anticipated solar eclipse of October 25, 2022, reduced sunlight by a mere average of 10.5% for two hours - hardly a meaningful challenge for spruce trees in the Lower Dolomites, with light levels exceeding the tree’s saturation point. Under such conditions, the adaptive value of anticipating such a minor and transient event appears negligible for plants that face dramatic fluctuations in light levels and temperatures, wind gusts, frost damage, etc., let alone daily transitions into the evening darkness, thus seriously undermining the evolutionary rationale of such hypothetical anticipatory responses. The authors further claimed that the anticipatory responses of the trees 14 hours prior to the solar eclipse relied on recollections of lunisolar gravitational force patterns of previous eclipse events, but close examination shows no spatiotemporal or magnitudinal similarities between successive eclipse events (Fig. S1). Further calculations demonstrated that differences in lunisolar gravitational force during solar eclipses and non-eclipse syzygies, such as during monthly new moon, as well as 14 hours before these events, are negligible and cannot be detectable by plants. In addition, the authors claimed that older trees not only demonstrated greater anticipatory responses but also communicated this information to their younger conspecific neighbours. Unfortunately, the study's findings and analyses neither demonstrated any adaptive value to the observed electrome activity, nor did it present any evidence for inter-tree communication, and for all we know, the observed coordinated electrical activity of the studied trees could have resulted from concurrent yet independent responses to external elicitation by a weather storm and a cluster of nearby lightning strikes 14 hours prior to the eclipse event (Fig. 2).

Lessons, implications and future challenges

The above analysis of Chiolerio et al. (2025) highlights a concerning tendency of some studies in the field of plant behaviour to prioritize captivating narratives over scientific rigor. To mature beyond speculation toward gaining true scientific credibility, studies should return to fundamental scientific principles, underpinned by logical and practical robustness. This demands meticulous observations and experiments designed with sufficient replications and repetitions to ensure statistical power, and appropriate controls that enable unequivocal attribution of the observed effects to specific factors in the most parsimonious fashion. Neglecting these norms may render even the most intriguing findings anecdotal, unfalsifiable and unscientific. Unfortunately, some high-profile work, while undoubtedly sparking public interest, has fallen short of these standards. For example, early interpretations of Simard's work on 'wood wide webs' at times extended beyond direct empirical evidence, leading to overstated claims about resource sharing between trees that, while fascinating, require more direct, controlled, and properly replicated studies to substantiate their underlying mechanisms and universality (Karst et al. 2023; Henriksson et al. 2023). Similarly, some of Gagliano's research on plant cognition and learning (Gagliano et al. 2016) could not be replicated, and has been criticized for experimental design, limited sample sizes, and questionable interpretations of the findings (Markel 2020). The study discussed here serves yet another blatant case for extravagance in speculation without scientific support. New scientific fields and paradigms can only develop through falsifiable hypotheses and reproducible evidence. Failing to meet these fundamental criteria risk remaining in the realm of pseudoscience, characterized by unfounded and incoherent claims.

Given that the electrome data has been recorded from *Picea abies* trees at the study location for longer periods (Chiolerio et al. (2022), it should be possible to further contrast the hypotheses presented by Chiolerio et al. (2025) and in this work by comparatively analyzing electrome data recorded during baseline periods, as well as before, during and after rain and lightning storms, new moons and solar eclipses.

Future research into the emerging field of electrical activity in trees, particularly inter-tree communication, is promising. Currently, our understanding is limited, with notable knowledge gaps concerning the precise information content of electrical signals and cues. How do they functionally reflect tree response and involved in the communication of various responses to e.g. drought, shade and herbivory? Such open questions can be addressed by carefully mapping tree electrome responses during both naturally occurring and experimentally induced stresses and challenges, while simultaneously monitoring morphogenetical, growth, and core physiological processes (e.g. Zhao et al. 2015). Special attention should be given to differentiating between passive and active electrical activity, as well as its potential involvement in adaptive signaling, coordinated responses among organs of the same tree to the same elicitors (Johns et al 2021) and communication between neighboring trees (Szechyńska-Hebda et al. 2022). Such knowledge is invaluable for advancing basic plant science and could inform climate adaptation strategies, sustainable forest management, and inspire novel technologies for environmental monitoring and smart agriculture (Volkov 2012, Coppedè et al. 2017).

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Competing interests

The authors declare no competing financial interests.

Author contributions

AN initiated the work and drafted the manuscript. HY provided the analyses of the lunisolar gravitational forces. Both authors reviewed the literature.

ORCID

Ariel Novoplansky 0000-0003-0988-786X

Hezi Yizhaq 0000-0001-7573-3303

Table 1. Contrasting key assumptions and claims presented by Chiolerio et al. (2025) with alternative perspectives.

Challenge	**Assumed or claimed by Chiolerio et al. (2025)**	**Alternative perspectives**
What is the anticipated functional challenge?	The Oct 25, 2022 solar eclipse was expected to present the *Picea abies* trees with a significant functional disruption.	The solar eclipse obstructed the sun by an average of 10.5% for two hours, during which light levels exceeded the tree's photosynthetic saturation point, and thus posed a transient and functionally negligible challenge for the trees.
What is the functional significance of the plant electrome?	"…electrome is an active, functional electrical or biochemical process that originates within an organism and is used for communication or coordination within the organism's body".	Plant's electrical activity is not necessarily active, adaptive, or used for communication. Importantly, the study did not present any evidence for adaptive responsiveness of the trees to the solar eclipse, let alone its correlations with electrome activity.
Can past solar eclipses inform trees about future ones?	Trees can anticipate solar eclipses based on past experiences.	Paths of solar eclipses are continuously changing and are spatiotemporally unique and thus cannot be utilized by plants to predict future eclipse events.
Do *Picea abies* trees collectively respond to solar eclipse?	Entanglement among trees allows collective responsiveness of *Picea abies* trees to the anticipated solar eclipse.	Synchronous responses could be attained by either concurrent yet independent responses to the same external cues or by interplant signalling (Fig. 1). These options are not mutually exclusive. The study presented no evidence to support either alternative.
Why larger and older trees presented greater electrical activity compared to their younger and smaller neighbours?	Older trees have experienced previous solar eclipses and "…have been connected for a longer time with the environment".	Trees act as electromagnetic antennae, with their reception capacity proportional to their physical size.
What is the advantage of synchronous anticipatory responses to solar eclipses?	Increasing survival and performance of individuals and their neighbours	As partial solar eclipse events do not present *Picea abies* trees growing at the study location with meaningful challenges, they are not expected to respond to them.
What elicited the heightened pre-eclipse electrome activity?	Anticipatory responses based of experiences of previous solar eclipses.	Drastic changes in atmospheric conditions, a notable rain event, and a cluster of nearby lightning strikes.

Fig. 1: Trees may synchronously respond to external stimuli via two not mutually exclusive mechanisms: independent responses to external elicitation (A) or inter-tree communication, whereby some trees perceive the external stimulus and sequentially communicate it to their neighbours (B).

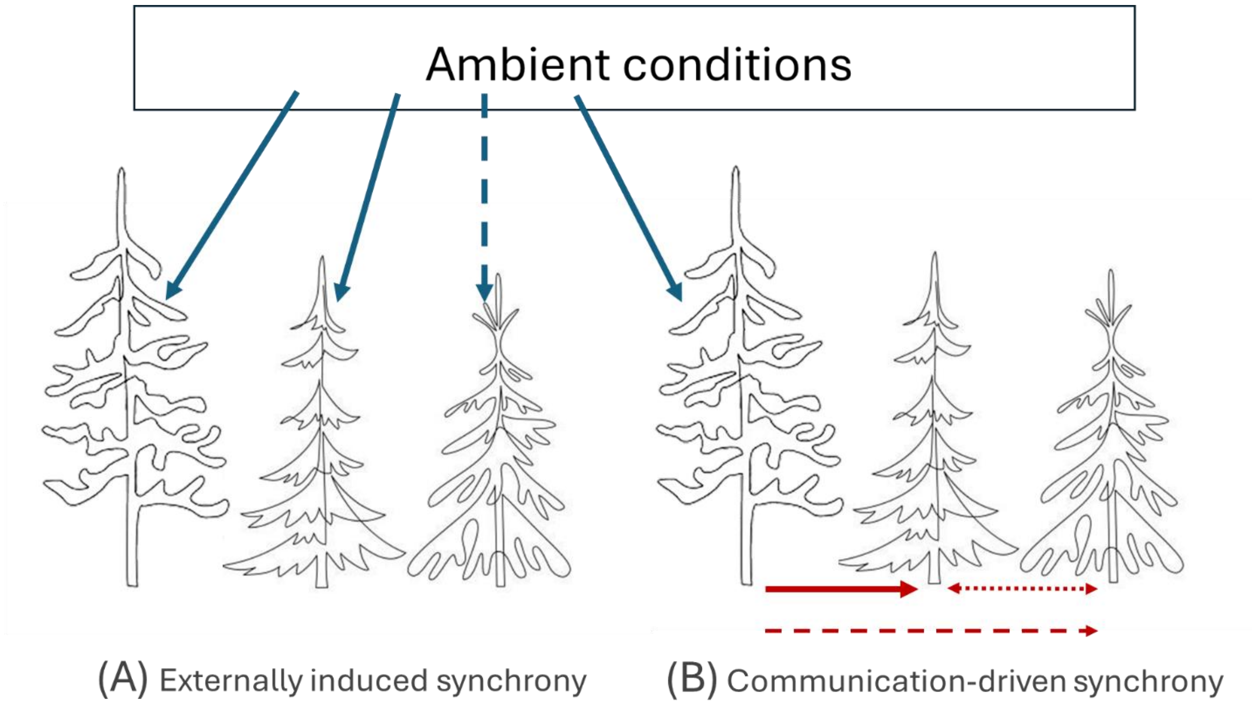
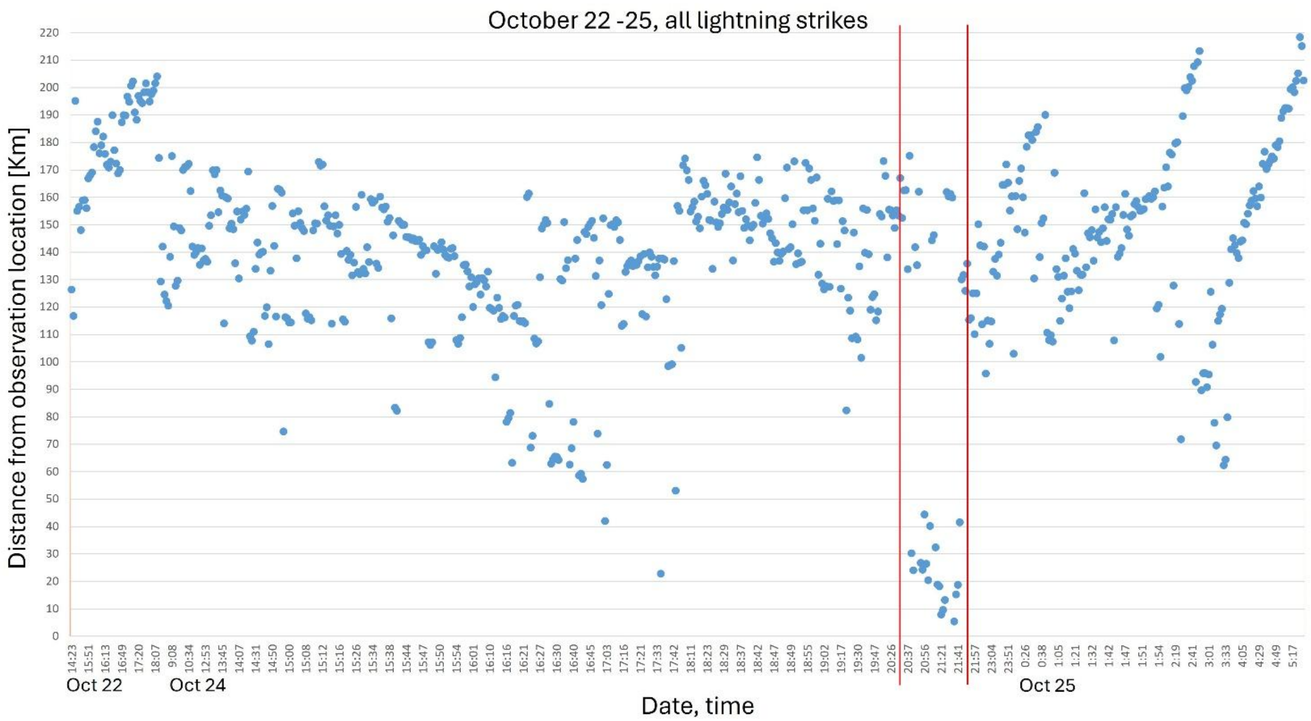
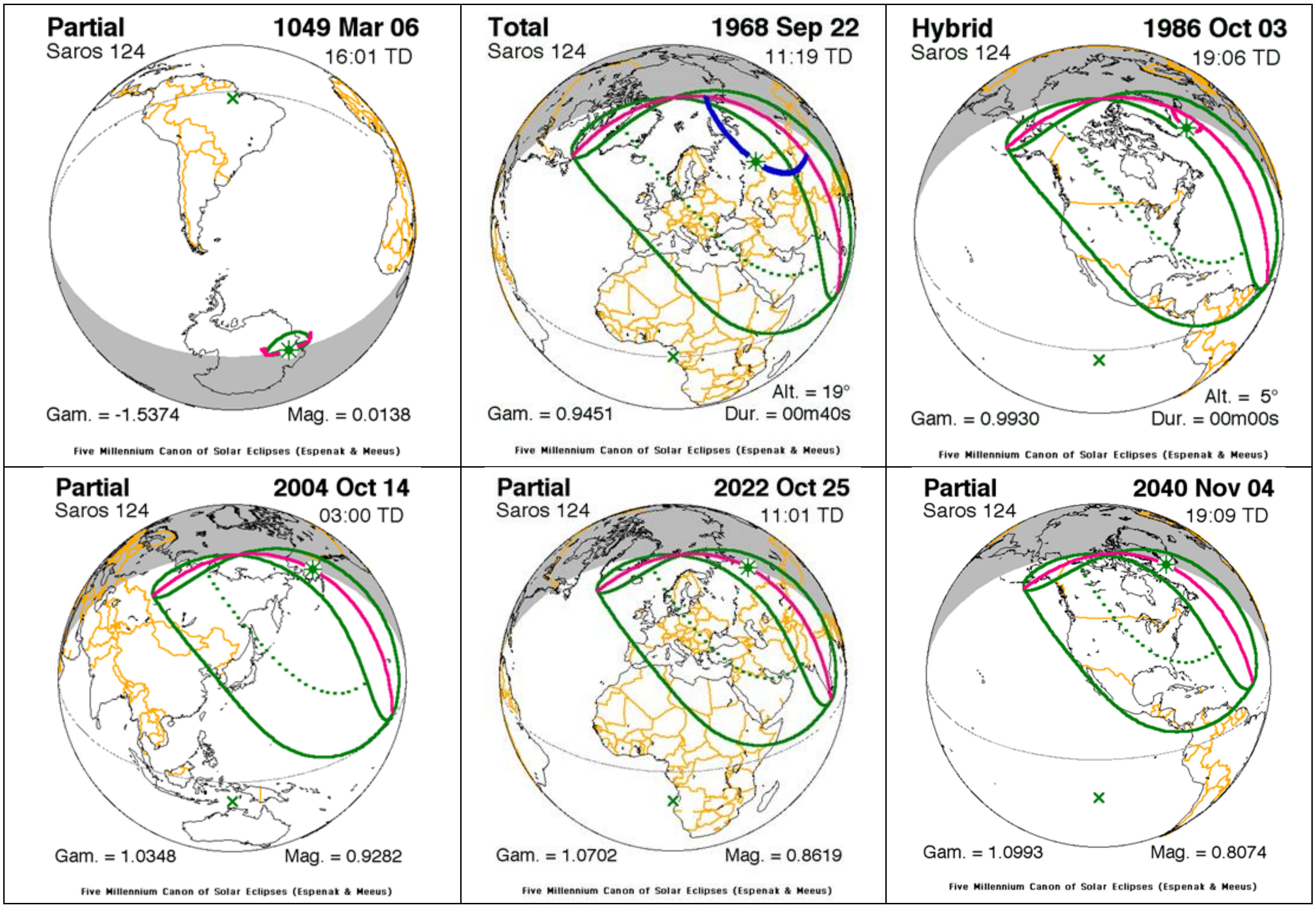


Fig. 2: All lightning strikes recorded within 200 km of the study site during a 96-hour period beginning at 00:00 on October 22, 2022. The period marked between the red lines depicts a cluster of lightning strikes ca. 14h before the October 25, 2022 solar eclipse.



Supplementary materials

Fig. S1: First, most recent, and next Saros 124 solar eclipses.



Explanations for symbols, signs, and markings (exemplified by the Oct 25, 2022 eclipse):

- Green Lines: the limits of visibility—areas where the eclipse is visible as a partial eclipse.
- Magenta Line: the central line where the eclipse reaches its maximum magnitude (i.e., the greatest coverage of the Sun by the Moon).
- Green 'X' Mark: the specific observation points or measurement locations used in eclipse modelling or data collection.
- "Partial Saros 124": this eclipse is part of Saros cycle 124, a periodic series of eclipses that recur approximately every 18 years, 11 days.

- "11:01 TD": the Terrestrial Dynamical Time of maximum eclipse—used in astronomical calculations.

"Gam. = 1.0702":

- Gamma is a measure of how centrally the Moon's shadow passes relative to Earth's center.
- A value > 1 means the eclipse is partial and the Moon's shadow misses Earth's center.

"Mag. = 0.8619":

- Magnitude refers to the fraction of the Sun’s diameter covered by the Moon at maximum eclipse.
- A value of 0.8619 means 86.19% of the Sun’s diameter was obscured at peak.

Source: Espenak, F., & Meeus, J. (2006). *Five Millennium Canon of Solar Eclipses*. NASA Centre for AeroSpace Information. *Color-enhanced rendering as* adapted from Fred Espenak, NASA Eclipse Web Site - http://eclipse.gsfc.nasa.gov/SEsaros/SEsaros.html.

https://eclipse.gsfc.nasa.gov/SEpubs/5MCSE.html

https://eclipse.gsfc.nasa.gov/solar.html

More information on Saros Series 124