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EDITORIAL

Atmospheric electricity: an underappreciated meteorological element governing biology and human well-being

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Atmospheric electricity has been studied since the early 1700s. Fueled by an interest in lightning, scientists aimed to unravel whether thunderclouds contained electricity in both the laboratory (Wall 1708) and in the atmosphere (Franklin 1751; Dalibart 1752; de Romas 1753; Cavallo 1776). However, electrification of the air was also detected during fair weather conditions (Lemonnier 1752), sparking a wider interest and centuries of studies on the origin and spatio-temporal variability of atmospheric electricity (for a detailed historical overview, see Nicoll 2012). This culminated in the insight that atmospheric electrical phenomena are sustained by a global atmospheric electric circuit (GEC) that is primarily driven by thunderstorm and shower cloud activity (Wilson 1906, 1920). Only relatively recently, scientists began to consider atmospheric electricity as a meteorological parameter potentially capable of driving biological processes. Work in the early twentieth century focused, for instance, on how ions can affect human health (e.g., Krueger and Smith 1958), or how atmospheric electricity could potentially enhance plant growth (Lemström 1890; Lodge 1908) or affect virulence in flu epidemics (Huntington 1920). To date, such viewpoints remain largely untested and inconclusive, yet remain ever so topical with increasing population densities and increasing pressures on both the physical environment and climate. This special issue unites new research that links atmospheric electricity with biology and human well-being that collectively highlight the importance of a rejuvenated interest in this field.

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Studying complex links between atmospheric electricity and biological systems as well as their interactions requires an integration of various parameters. A multi- and transdisciplinary approach is therefore needed that considers concepts and methodologies from disparate scientific disciplines ranging from data science, meteorology, and atmospheric physics to biological and medical sciences. It is thus essential that knowledge can be shared between different disciplines. Accordingly, Fdez-Arroyabe et al. (2020) develop in this special issue a glossary of relevant terms and concepts to facilitate integration in common research and to provide a valuable resource for those seeking an understanding of atmospheric electricity and its links to biological systems. Likewise, to allow for further retrospective analysis of available data, a semantic approach is necessary. To this end, Savoska et al. (2020) develop an ontology for existing data on atmospheric electricity within the context of biological systems that are distributed over many databases. Establishing common terminology and an environment for data sharing will benefit the sharing of interdisciplinary research progress and facilitate data reusability across the research communities.

Various sources of electricity are pervasive in the atmosphere, and each has different degrees of variability and potential interactions with biology. On a global scale, electromagnetic fields are ubiquitous, and their links to biology have been studied more extensively over the last century (e.g., König et al. 1981). More locally, research has demonstrated the biological impacts of lightning strikes (e.g., Demanèche et al. 2001; Schaller et al. 2013), the production of ions (e.g., Matthews et al. 2010), radionuclides (e.g., Krivolutsky and Pokarzhevsky 1992), and the increasing use of electrical technology. More recently, evidence has emerged that biology is linked with static electric fields that are pervasive throughout the Earth's atmosphere (e.g., Clarke et al. 2013; Morley and Robert 2018; Hunting et al. 2019). In this special issue, Hunting et al. (2020) provide an overview of this wide array of atmospheric electrical phenomena and their ties to biology, in which conceptual and technical challenges, as well as

opportunities for future research, are identified. This special issue further features reviews that provide in-depth discussions of the available literature on specific atmospheric electrical phenomena and their relevance for biology. Cifra et al. (2020) assess mechanisms of how atmospheric electromagnetic phenomena can act at the molecular and cellular level, showing that multiscale modeling approaches are crucial to understanding whether and how electrical field changes at the molecular level are reinforced across biological scales to the level of an organism. Ćujić et al. (2020) review research focusing on the abundant radionuclides 222Rn, highlighting its significance as contributors to the total dose received by both humans and wildlife from natural radiation sources. Price et al. (2020) discuss how extremely low frequencies may have provided the evolutionary electrical background at which cellular electrical activity has developed. These studies provide a valuable up-to-date understanding and highlight the complexity and interdisciplinary nature of the relationship between atmospheric electricity and the organization and functioning of biological systems over a wide range of spatial and temporal scales.

Human health is strongly governed by their physical and chemical environment, and it is well known that various atmospheric processes affect human well-being at multiple scales (Fdez-Arroyabe 2015). For instance, atmospheric pollution globally accounts for approximately 9 million deaths, annually (Burnett et al. 2018). The role of atmospheric electricity for human well-being, however, often remains ambiguous due to a large number of confounding variables in atmospheric parameters, geographic distributions, and variability in lifestyle. Despite this, links between atmospheric electrical phenomena and human health become increasingly apparent. In this special issue, Kourtidis et al. (2020) show that circulation weather types, in addition to temperature and humidity, affect the electric state of the atmosphere, thereby identifying an important component within a complex interdependent set of physical and biological linkages. Riancho et al. (2020) review existing literature on links between electromagnetic fields and neurodegenerative diseases and discuss the role of electromagnetic radiation as a potential non-invasive therapeutic strategy for some neurodegenerative diseases. Molina-Gómez et al. (2020) analyze field-collected data using geostatistical and machine learning tools to identify and analyze the areas in which primary socioeconomic and environmental conditions contribute to the presence of symptoms associated with respiratory diseases. The links and statistical tools presented in these articles are essential in anticipating environmental health threats and developing early warning systems that could mitigate risks for individuals and populations.

Collectively, the work presented in this special issue unveils the intimate connectivity of atmospheric electricity with biology. The contributions show how atmospheric electricity can govern human well-being as well as a wide array of organisms and the processes they sustain and therefore serve as an appraisal to consider atmospheric electricity as a significant direct and indirect driver of biology. These studies highlight the interdisciplinary and complex nature of this research field, in which many exciting and promising new research avenues become visible that can lay the foundation for novel empirical research and much needed conceptual and operational frameworks.

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