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Atmospheric Electrical Parameters and Their Variations: A Review on Ecological and Air Pollution Impacts

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Abstract: Atmospheric electrical parameters, including electric field, ion concentrations, and conductivity, play a crucial role in understanding environmental changes. This review explores the relationship between these parameters and ecological as well as air pollution variations. Various factors such as particulate matter, gaseous pollutants, and meteorological conditions influence atmospheric electricity. The study also highlights the implications of these variations on climate and ecosystem stability. Future research directions are proposed to improve monitoring and predictive capabilities.

Keywords: Atmospheric electricity, air pollution, ecological impact, electric field, ion concentration, climate change

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INTRODUCTION

Atmospheric electricity is a key indicator of environmental stability. Changes in atmospheric electrical parameters can signal alterations in pollution levels and ecological conditions. Understanding these interactions is vital for assessing environmental risks and climate change impacts.

The electrical characteristics of the atmosphere play an important role in Earth's atmosphere, impacting a wide range of atmospheric processes and interacting with environmental and pollution concerns. The electric field, ion concentration, air conductivity, and distribution and frequency of lightning are all examples of such properties. The intricate dynamics of the atmosphere and its wider environmental and climatic consequences can only be understood with a firm grasp of these characteristics. Thunderclouds are the primary sources of the atmospheric electric field, which is caused by the separation of charges. The shifting of ice and water molecules inside the clouds causes this separation by generating areas of positively charged and negatively charged space as a result of collisions and processes such as electron transfer. Factors including weather patterns, solar activity, and geographical characteristics impact the electric field that stretches from the Earth's surface to the ionosphere. The field's intensity and direction change with height and weather, and it's usually expressed as volts per metre (V/m).

IMPACT OF AIR POLLUTION ON ATMOSPHERIC ELECTRICITY

Pollutants such as sulfur dioxide, nitrogen oxides, and particulate matter modify ionization processes, altering conductivity and electric field strength. Studies have shown a correlation between increased pollution and reduced atmospheric conductivity.

ECOLOGICAL IMPLICATIONS

Variations in atmospheric electricity affect weather patterns, precipitation, and cloud formation, ultimately influencing biodiversity and ecosystem health. Prolonged disruptions can contribute to climate anomalies.

ATMOSPHERIC ELECTRICAL PARAMETERS

The concentration of ions in the atmosphere is the density of charged particles. Many processes, including as interactions with cosmic rays, radioactive decay, and surface radioactivity, contribute to the production of these ions. Greater exposure to these ionising processes causes the ion concentration to be higher in the lower atmosphere (troposphere), which in turn increases with increasing altitude. Because of their effects on air conductivity, cloud formation, and precipitation, ions are essential components of atmospheric electricity. The atmospheric electric field and the occurrence of phenomena like lightning are influenced by the total concentration and balance of positive and negative ions. There is a one-to-one relationship between ion concentration and air conductivity, a measurement of the atmosphere's capacity to carry electrical current. An increase in the concentration of free ions in the air makes it more conductive, allowing electric charges to travel more easily. As a function of height, latitude, and other geographical and climatic factors including humidity and pollution levels, the air's conductivity changes. As a result of reduced ion generation, conductivity is often lower at higher altitudes, although it is higher in areas with abundant natural or man-made ionising sources. Predicting and modelling atmospheric electrical events, such as lightning and other types of electrical discharge, requires an understanding of air conductivity.

ELECTRIC FIELD

An essential electrical characteristic of the atmosphere is the electric field, which is defined as the force per unit charge acting on an atmospheric charged particle. It has a major impact on the dynamics of air pollution and ecological systems, and it is essential to many atmospheric processes and occurrences. To fully grasp the far-reaching effects of atmospheric electricity on environmental health and atmospheric sciences, one must be familiar with the dynamics of the electric field in the atmosphere, including its fluctuations and interactions with ecological elements and air contaminants. Because electric charges are constantly being generated and dissipated, the Earth's atmosphere has an electric charge. Thunderstorms and electrified clouds keep the world's electrical circuit running by generating electricity and sending it back to Earth through the atmosphere's fair-weather areas. There is usually a downward-directed electric field at the surface of the Earth with an average intensity of around 100-150 volts per metre when the weather is nice. The difference in charge between the upper atmosphere and the Earth's surface causes this electric field.

Vegetation, soil moisture, and terrain are some of the ecological elements that might affect the local electric field. For instance, vegetation has the ability to influence the electric field in the atmosphere via changing the surface roughness and releasing ionising biogenic volatile organic compounds (BVOCs). As a conduit for charge transport, dense vegetation can also add to higher air conductivity. Soil moisture also affects the electric field via changing the ground's conductivity. Soils that are wet have a higher surface conductivity, which changes the intensity of the electric field close to the ground. fluctuations in solar radiation, temperature, and air variables impact the electric field's diurnal and seasonal fluctuations. As a result of the increased ionisation brought about by the sun's UV radiation, the electric field strength tends to diminish during the day. Typically, ionisation rates drop during night, leading to a stronger electric field. The electric field experiences seasonal variations due to changes in solar activity, weather patterns, and biological changes. For example, in contrast to the more stable circumstances in winter, electric field changes might be more pronounced during the summer due to thunderstorms and heightened convective activity.

ECOLOGICAL FACTORS INFLUENCING ATMOSPHERIC ELECTRICAL PARAMETERS

An important part of the ever-changing relationship between the environment and the atmosphere is the impact of ecological variables on electrical characteristics in the atmosphere. To grasp the intricacies of atmospheric processes and their effects on ecological systems, one must grasp this complicated link. Vegetation, soil moisture, and temperature/humidity conditions are three important biological elements that impact electrical parameters in the atmosphere. The modulation of surface properties and atmospheric ionisation are two ways in which vegetation significantly affects atmospheric electrical parameters. Biogenic volatile organic compounds (BVOCs) have a major influence on atmospheric chemistry and ionisation processes, and vegetation is a major producer of these molecules. Vegetation, including trees and bushes, releases terpenes and isoprene, which are volatile organic compounds (VOCs). These gases are involved in photochemical processes that create atmospheric ions and secondary organic aerosols. Atmospheric electrical processes rely on these ions, which include both positively and negatively charged cations and anions, and which influence electric field distribution, conductivity, and charge transport. Vegetation also changes the local electric field and ion concentration profiles by influencing surface charge distribution, aerodynamic roughness length, and surface roughness, all of which affect atmospheric electrical characteristics. Research on the ecological effects of changes in atmospheric electrical characteristics must take vegetation dynamics into account due to the intricate web of relationships between ionisation processes, atmospheric chemistry, BVOC emissions, and vegetation.

IMPACT OF AIR POLLUTION ON ATMOSPHERIC ELECTRICAL PARAMETERS

One of the most pressing environmental problems today is air pollution, which has far-reaching effects, including changes to electrical properties in the atmosphere. More and more research is pointing to the complex ways in which air contaminants affect atmospheric electricity and other factors, highlighting the interconnected nature of the two. Changes to the atmospheric concentration and distribution of ions are a major impact of air pollution on electrical characteristics of the atmosphere. There can be changes in the concentration and behaviour of atmospheric ions as a result of interactions with pollutants including sulphur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM). One example is the oxidation of sulphur dioxide to sulfuric acid aerosols. These aerosols can then be used as building blocks for new ions to form through a process called ion-induced nucleation. Atmospheric conductivity and electric field strength can be influenced by this process, which changes the ion balance. Similarly, nitric acid and nitrate aerosols can be formed by NO_x emissions, which in turn affect electrical characteristics and ion chemistry.

By absorbing ions and changing their mobility, particulate matter, particularly tiny particles known as PM2.5, can directly impact electrical characteristics in the atmosphere. In order to facilitate the transfer and redistribution of charged species in the atmosphere, PM2.5 particles might serve as carriers for them. The electric field properties and air conductivity can be affected by this interaction, which can change the distribution of ions. Clouds and precipitation can have their microphysical characteristics altered by PM, which in turn affects lightning activity and the frequency of electrical discharges in the sky.

Pollutants affecting ionization

A vast variety of chemical chemicals released into the air by both natural and human-caused processes are known as pollutants impacting ionisation. Atmospheric electrical characteristics including electric field strength, ion concentration, and air conductivity can be affected by these contaminants because of their potential to drastically alter atmospheric ionisation processes. If we want to know how pollutants affect air pollution dynamics, atmospheric chemistry, and, in the end, people's and the planet's health, we need to understand the intricate interactions between contaminants and ions in the air. The ionisation process is negatively impacted by sulphur dioxide (SO_2) and other contaminants. Industrial operations, fossil fuel burning, and volcanic eruptions are the main sources of sulphur dioxide emissions. Sulphate aerosols and sulfuric acid are produced when sulphur dioxide (SO_2) is released into the atmosphere and goes through photochemical reactions. By facilitating the creation of cloud droplets and influencing cloud microphysics, these aerosols can serve as condensation nuclei for water vapour. Sulfuric acid and ammonia in the air can react to produce ammonium sulphate particles, which in turn affect aerosol characteristics and ionisation levels in the air. The charging and mobility of atmospheric ions are impacted by the presence of sulphate aerosols, which promote aerosol-electricity interactions.

In addition to other pollutants, nitrogen oxides (NO_x) such as nitric oxide (NO) and nitrogen dioxide (NO_2) have major consequences for the ionisation of the atmosphere. The combustion process is the main source of nitrogen oxide emissions from cars, power plants, and industrial sites. Ozone (O_3) and secondary organic aerosols are byproducts of photochemical reactions between NOx and volatile organic compounds (VOCs) in the atmosphere. A potent oxidising agent, ozone, can affect atmospheric ionisation by its combination with water vapour to generate hydroxyl radicals (OH). These radicals are essential in the ion-neutral processes that generate and remove ions from the atmosphere. In addition, nitrogen oxides have the potential to play a role in the creation of nitrate aerosols. These aerosols have the ability to reduce ion concentrations in the atmosphere and even change electrical conductivity. Another important factor influencing atmospheric ionisation is particulate matter (PM), which consists of a wide variety of liquid and solid particles in suspension in the air. Pollutants in the atmosphere may come from a variety of places, including things like cars, factories, farms, and even natural disasters like dust storms and wildfires. Airborne gaseous contaminants and atmospheric ions can be transported and dispersed by fine particulate matter (PM2.5) and coarse particulate matter (PM10). In addition to their role as attachment nuclei, PM can promote the creation of charged aerosols and the development of electrically charged particles through collision and coagulation processes, both of which can have an impact on atmospheric ionisation.

The ionisation of the atmosphere is also affected by another significant group of contaminants, volatile organic compounds (VOCs). Many different things, such car exhaust, industrial operations, and plants, release volatile organic compounds into the air. Atmospheric VOCs react photochemically with nitric oxide and other oxidants to produce reactive oxygen species and secondary organic aerosols. The speeds of ion-neutral reactions and aerosol formation processes are modulated, the distribution and quantity of charged species are changed, and the atmospheric ionisation can be affected by these interactions. There are a number of secondary pollutants that can impact atmospheric ionisation, and volatile organic compounds (VOCs) are one of them. Atmospheric radicals like peroxy radicals (HO2) and alkylperoxy radicals (RO2) can be produced by VOCs and then contribute to chain reactions that lead to the creation of ozone.

Particulate matter and conductivity

The term "particulate matter" (PM) describes the complex combination of airborne solid particles and liquid droplets. Dust and pollen are examples of naturally occurring particles, whereas artificial sources such pollution from cars and factories produce larger and more diverse particles. Due to their substantial health and environmental impacts, the most often researched fractions of particulate matter (PM) are PM2.5 (particles with a diameter of 2.5 micrometres or less) and PM10 (particles with a diameter of 10 micrometres or less). Impacts on air conductivity by particulate matter are an important facet of their interaction with the atmosphere. The capacity of air to carry electrical currents, or air conductivity, is influenced by the presence of charged particles and ions in the environment. Air conductivity can be affected by particulate matter in a number of ways, which can cause both temporary changes and long-term patterns in conductivity levels.

In the atmosphere, charged ions can be carried by particulate matter. Charged particles can draw in air ions of the opposite polarity when they undergo processes like frictional charging or chemical reactions. The term for this phenomenon is ion scavenging, and it changes the air's conductivity and ion concentration by causing ions to accumulate on particle surfaces. The size, content, and surface area of the particles determine the extent to which this effect is felt; the bigger the surface-to-volume ratio of the particles, the more noticeable the impact of the smaller ones. Airborne aerosols, which are essential in ionisation processes, may be formed from particulate matter by using it as a nucleus. Aerosols are microscopic particles in the air that can undergo photoionization, radioactive decay, and other processes to form charged ions when they come into contact with solar radiation, cosmic rays, and other forms of energy. Air conductivity is enhanced by these ions, which also aid electrical processes like lightning production and corona discharge. Air conductivity may be affected on both a local and global level by particulate matter, particularly hygroscopic particles such as nitrate and sulphate aerosols, which can boost aerosol formation and increase ion generation.

Size distribution and surface charge are two physical characteristics of particulate matter that influence its capacity to absorb atmospheric water molecules. The process of hygroscopic growth occurs when hygroscopic particles take in water and then develop a thin coating of water. Because it acts as a conduit for ions to move through and makes it easier for them to move about inside the particle matrix, this water layer improves the conductivity of the particles. Hygroscopic expansion also changes the electrical characteristics of particle ensembles, which impacts cloud formation, precipitation, and atmospheric stability, among other processes. Meteorological circumstances, air chemistry, and source characteristics are only a few of the variables that might affect the seemingly simple link between particulate matter and conductivity. For example, air conductivity can rise in humid environments because particles are more hygroscopic and can absorb more water, but it can fall in dry environments because particles are less hygroscopic and conductivity is lower. Atmospheric electrical characteristics like electric field strength and ion concentration can be affected by changes in PM composition caused by seasonal fluctuations or emission sources, which in turn affects its conductivity-enhancing capabilities.

ATMOSPHERIC ELECTRICITY

Heat and energy are transferred from the surface of the Earth to the atmosphere by conduction. The atmospheric boundary layer (ABL) is a potential interaction zone that arises when heat is transferred from Earth's surface. The surface is mainly affected by the heating and cooling processes, the evaporation and condensation, and the atmospheric drag. Up to a few kilometres into the lower atmosphere, these processes generate vertical convection and transmit heat, moisture, and air currents. Turbulence, wind pattern contours, ambient temperature, and water vapour are all governed by these ABL fluxes. The ABL can have a thickness anywhere from tens of metres to several kilometres since the depth of penetration is dependent on the kind, strength, and duration of surface fluxes as well as large-scale climatic circumstances.
Since ABL is so close to the surface of the Earth, most atmospheric processes involving atmospheric electrical processes have taken place there. Famous physicists like Franklin, Lemonnier, and Coulomb laid the groundwork for our current knowledge of the electric nature of the environment, and for over two centuries, people have worked to decipher fundamental ideas. It was a stunning occurrence to see how the weather had such a profound impact on the electrical characteristics of the air we were breathing, particularly the vertical electric field. Therefore, according to Lord Kelvin, an electrometer may help us comprehend the electrical character of the environment, which would allow us to make more precise weather predictions. The difficulty in comprehending and reliance on electrical characteristics due to the large range of variables has mostly prevented this hopeful thinking from being put into effect. Understanding atmospheric processes in a vacuum is challenging due to the interconnected nature of these processes. But there aren't many major factors that affect the weather. In the study of atmospheric electricity, isolating the effects of different sources becomes more difficult. In order to comprehend the delicate phenomenon of atmospheric electricity, one must account for fluctuations in both space and time. As an example, a little perturbation of the spacecharge density in ABL can have a large impact on the electric-field fluctuations that govern worldwide thunderstorm activity.

There have been many applications for the data collected from the electrical properties of the atmosphere over the years. Atmospheric electrical parameter measurements may be used to study and satisfy a number of processes, including the large-scale behaviour of the global electric circuit, turbulence in the mixing layer, and researchers' curiosity. Finding and removing the impacts of irrelevant data from real data points is a lengthy task because of the intricacy of the problem and the affects of many elements. Therefore, researchers still need to inform their peers about the whole spectrum of impacts and contamination if they wish to see undesired data completely removed from current datasets. Atmospheric electrical fluctuations react to a wide variety of phenomena, which is fascinating to watch because these variations are typically rather uncontrollable. Meteorological factors, air pollution, boundary layer turbulence, and environmental radioactivity all have an impact on atmospheric electricity, but the inverse is not true. Research on atmospheric electricity is fascinating and truly interdisciplinary, bringing together experts from fields as diverse as biology, planetary physics, meteorology, mathematics, chemistry, space science, and physics. Therefore, in order to grasp the links between ABL processes and atmospheric electricity, it is crucial to understand the many elements that impact these parameters.

RADIOACTIVITY IN THE ATMOSPHERE

One way to identify a nucleus is by its radiation, and the energy spectrum is the primary metric by which various types of radiation are classified. Solar radiation, which causes our eyes to focus and our bodies to heat up, is by far the most well-known type of radiation. Radiation from the sun is necessary for all forms of life on Earth, yet in excess it can be harmful to people. Various wavelengths of radiation, ranging from low-frequency radio waves to high-frequency γ-rays, are contained in solar radiation. The medical field makes extensive use of radiations with frequencies above the ultraviolet spectrum. Ionising radiation is the collective name for several forms of radiation, and it is known to cause serious harm to living things, especially tissues. High doses of radiation pose serious health risks to humans. It is common practice to divide radiations into two groups: those that originate in nature and those that originate from humans. Of all the natural radiations, the one caused by radioactivity is the most intriguing. The release of energy in the form of radiations by an unstable atomic nucleus is known as radioactivity. Cosmogenic, man-made, and primordial radioactive nuclide sources are all present.

RADON AS A TRACER IN ATMOSPHERIC PROCESSES

The capacity of the atmosphere to remove pollutants and excess heat inside an urban canopy is governed by the atmospheric mixing condition. The stability parameter measures the amount of mixing in the atmosphere. On the other hand, meteorological stability measurements collect data on wind speed and temperature at the surface, as well as their vertical gradients, in an effort to determine the combined effects of mechanical mixing and thermodynamics. In addition to being prohibitively expensive or labor-intensive to apply across large areas, these approaches are either categorical or have unrealistic ideal fetch requirements. When it comes to understanding the cumulative impacts of all nearsurface atmospheric mixing processes, very few studies have demonstrated that radon measurements alone are sufficient. Nighttime, as opposed to daytime, and winter, as opposed to summer, are the seasons when the phenomenon is most noticeable. Emissions of radon are mostly limited to and spread across an unsaturated, non-frozen surface of the Earth. Radon flow can be locally altered on periods ranging from a few seconds to days by meteorological factors such humidity, temperature, wind speed, pressure, and rainfall. In contrast to emissions caused by humans, average emissions during synoptic to seasonal periods are more stable. Because of its longer half-life, Radon is best used in studies involving the atmosphere. While the synoptic period is sufficiently lengthy in comparison to mixing timeframes inside the boundary layer, the likelihood of atmospheric build up is lower over longer periods. Therefore, Radon is seen as a cautious tracer for investigations comparing day and night mixing. Because of its unique physical properties, Radon may be used as a reliable indication of the cumulative effects of all vertical mixing processes that occur close to the surface.

THE ORGANIZATIONAL FRAMEWORK FOR RADON MONITORING

Multiple 222Rn observing sites in India are accessible for round-the-clock tracking. Radon, Thoron, and its offspring levels have been constantly monitored in various contexts over the past five decades by research groups at Bangalore University, Gulbarga University, University of Mysore, Kuvempu University, and Mangalore University.

The radon measurements taken on the ground were part of a larger initiative that included national, regional, and international initiatives, and their impact was seen on a global and regional scale. The World Meteorological Organisation (WMO) runs the Global Atmospheric Watch (GAW), a worldwide initiative that brings together nations including Japan, China, India, and Australia to set radon baseline studies. Since its inception in 1989, GAW has been home to several atmospheric scientific research and monitoring projects run by the World Meteorological Organisation (WMO), including BAPMoN and GO3OS. Given the extensive network under the GAW programme, the dataset is crucial for comprehending the interplay between studies of global and regional climate, air mass movement, and long-term changes in atmospheric composition. The Australian Nuclear Science and Technology Organisation (ANSTO) has launched a programme to use radon in atmospheric research by doing radon experiments at several GAW sites. By combining the efforts of ACE Asia and ANSTO, the experimental scientific value is increased, and a synergy between several rigorous field programmes is provided.

MEASURED PARAMETERS OF METEOROLOGY

Regular meteorological observations have been conducted for millennia for the purposes of weather forecasting and climatological study. Only after statistically recording medium- and long-term atmospheric conditions can the collected data be assessed and understood. Transportation and communications, including air, sea, and ground traffic, rely on measurements and observations made in the Boundary Layer, which is located near to the ground, to gather data. As seen graphically in Figure 1.6 the sun's rays are the primary driver of atmospheric temperature and other meteorological variables.

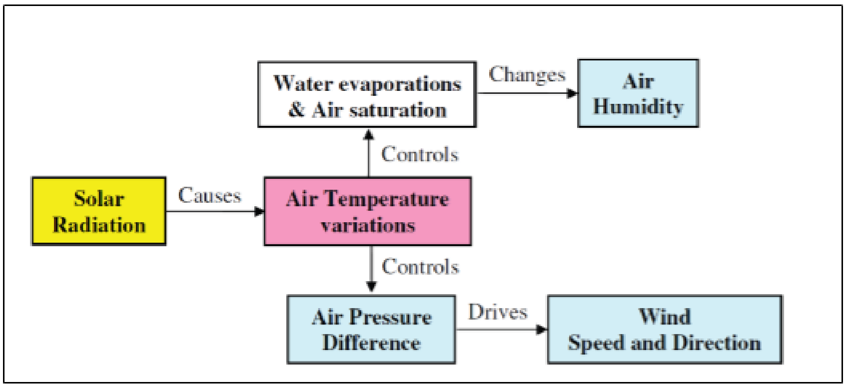

Figure 1: Diagram showing the driving process of meteorological parameters

Air pollution, avalanche warning, the renewable energy sector, agriculture, forestry, water distribution and supply, urban and regional planning, and meteorological characteristics are key areas of research. As an example, in order to evaluate and understand gas emission measurements, it is necessary to compare them to meteorological data that was collected at the same time.

When it comes to climate and weather, the structure of the atmosphere near the ground is crucial. Both the temperature and the pressure of Earth's atmosphere are influenced by the radiation from the sun. To a greater degree, the physical and chemical process is controlled by the atmospheric temperature and water vapour concentration. Turbulence in the atmosphere is the main culprit for the short-term fluctuations that might affect any meteorological parameter. Finding the average values from the actual measurements taken over a certain time period is essential for assessing these patterns. Typically, the temperature cycle is periodic, with the lowest point occurring just after sunrise and the highest point occurring in the middle of the day. Radiation values' temporal and spatial properties are affected by the properties of the ground surface in the atmosphere near the ground.

CONNECTION BETWEEN ATMOSPHERIC ELECTRICAL PARAMETERS, ECOLOGY, AND AIR POLLUTION

Air pollution, ecology, and electrical characteristics in the atmosphere all interact in various ways, highlighting how complicated Earth's natural systems are. The strong effect of electrical currents in the atmosphere on biological processes and the inverse effect of environmental variables and air pollution on electrical parameters in the atmosphere form the core of this nexus. Several phenomena are included in atmospheric electrical characteristics, such as electric fields, ion concentrations, air conductivity, and distribution and frequency of lightning. Both the comprehension of meteorological events and the moulding of ecological dynamics are greatly influenced by these characteristics. Plant development, seed germination, and the actions of creatures like birds and insects are all affected by ion concentrations and electric fields. Intricate feedback loops between terrestrial ecosystems and the atmosphere may be created by soil moisture, plant density, and temperature gradients, which can greatly influence atmospheric electrical properties. Due to the fact that the distribution of charges in the atmosphere is impacted by processes such as evaporation, condensation, and precipitation, the water cycle is intimately related to atmospheric electricity. On the other hand, electrical characteristics in the atmosphere are significantly affected by ecological variables. As an example, vegetation not only absorbs and reflects changes in atmospheric electricity, but it also modifies it. Plants and trees emit volatile organic chemicals that have the potential to affect electric field dynamics and air ionisation. Atmospheric conductivity, which in turn affects the distribution and strength of electric fields, is strongly affected by the moisture content of soil and plants. Pollutants in the air can also mess with these complex ecological-electrical relationships. When gases, aerosols, and particulate matter are released into the air, they can change the electric field intensity, ion concentrations, and atmospheric conductivity.

For example, industrially produced sulphur dioxide and nitrogen oxides can react with atmospheric components to create aerosols. These particles then have the ability to influence electrical characteristics in the atmosphere by acting as charge carriers. Particulate particles emitted by vehicles or burned biomass can potentially act as cloud nuclei, affecting the distribution of precipitation and the frequency of lightning strikes. In order to tackle urgent environmental issues like climate change and biodiversity loss, it is essential to comprehend the relationship between electrical properties of the atmosphere, ecology, and air pollution. Physiology of plants and animals, as well as nutrient cycling, may be impacted by changes in electrical characteristics of the atmosphere, which can cause a domino effect on ecosystems. On the other side, human-caused pollution and ecosystem deterioration may throw off the atmospheric electrical balance, which in turn worsens environmental degradation. This means that protecting ecosystems and reducing air pollution are critical for the survival of future generations as well as for the planet itself. Recent technological developments in areas like numerical modelling and remote sensing have opened up new avenues for understanding the interplay between air pollution, ecology, and atmospheric electricity. To tackle these interrelated environmental issues and promote long-term solutions, it will be crucial to combine methods from other scientific fields, such as ecology, environmental engineering, and atmospheric science. In the end, we may learn more about how our world works and strive for a better relationship with nature if we can decipher the complex relationships between electrical characteristics in the atmosphere, ecology, and air pollution.

CONCLUSION

Atmospheric electrical parameters serve as vital indicators of environmental changes, particularly in relation to air pollution and ecological stability. The findings from various studies confirm that pollutants significantly alter electric field strength, ion concentrations, and air conductivity. These disruptions impact weather patterns and ecological systems, necessitating better monitoring strategies. Future research should focus on integrating atmospheric electrical studies with environmental management policies to mitigate adverse effects.

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