

Atmospheric Electricity: Sources, Dynamics, and Impacts on the Environment

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ABSTRACT

This study is a review of the sources, dynamics and impacts of atmospheric electricity on the environment. Atmosphere ions are responsible for a weak flow of atmospheric electricity. These atmospheric ions are generated from different sources such as cosmic rays, radioactive gases, air radiolysis, lightning, waterfall, corona discharge, combustion and radioactive effluent from nuclear tests. These ions have different mobility depending on their sizes and the kind of charges they carry. The potential gradient between the atmospheric air and the earth's surface causes ions to move from the atmosphere, which is the positively charged region to the earth surface, which is the negatively charged region. The electric field in the air near the earth surface is 100 V/m. Negative small ions have higher mobility than positive small ions. High concentration of positive air ions poses a serious threat to human health, but negative ions promote the well-being of humans and living organisms.

Keywords: Atmospheric Electricity, Sources, Dynamics, Impacts, Environment.

Introduction

The universe is said to be electrically neutral, but material bodies and the atmosphere can become charged as a result of interactions between the constituent molecules or particles or changes in the environment in which these materials exist. For instance, the dynamic nature of the atmosphere and their interaction with both solar and cosmic radiation will make it impossible for the atmosphere to be totally neutral. Kalchikhin et al. (2020) posited that clouds, precipitation and other atmospheric phenomena contribute substantially to changes in the electrical state of the surface atmosphere. Thus, there exists a weak flow of electric current throughout the global atmosphere due to the presence of ions. Franklin was the first to offer an explanation of a global flow of moist electrified air (Williams, 2015).

Sources of Atmospheric Ions

It has been noted that cosmic rays and background radioisotopes are the common natural ionization sources that give rise to the partial electrical conductivity of atmospheric air (Harrison, 2005). Harrison (2005) posited that these “small ions are continually produced in the atmosphere by the radiolysis of air molecules”. Atmospheric ions come from sources such as lightning, waterfall (Lenard effect), corona discharge, and combustion (Li et al., 2015). Other sources include “soil radioactivity and radioactive gases from the earth and ^{85}Kr routinely released from nuclear reactors” (Hale, 2003); as well as radioactive effluent from nuclear tests (Popov et al., n.d). Biogenic charge in the atmospheric can possibly emanate from sources such as swarming insects and birds (Badger et al, 2015).

Dynamics of Atmospheric Ions

The flow of ions from positively charged atmosphere to the negatively charged earth surface is due to atmospheric potential gradient (Morley & Robert, 2018). This atmospheric potential gradient is 120Vm^{-1} over a flat field on a

day with clear skies (Morley & Robert, 2018). Atmospheric ions can be categorized into free-floating electrons, ionized atoms, small ions, large ions and middle ions. Small ion is a singly charged atmospheric molecule (American Meteorological Agency, 2012). Small ion molecules consist of 2 to 30 molecules, large ions are small ions absorbed by dust, mist and any other tiny particle (Nemoto, 2020). Small ions have higher mobility, diffusion coefficient and therefore, they are largely absorbed by the human body than large ions of the same quantity (Nemoto, 2020). Small ions have a mobility range between 0.4 and 0.8 (cm²/vs) while that of large ions is between 0.0005 and 0.01cm²/vs. Meaning that small ions have slightly higher mobility than large ions. Similarly, positive small ions have low mobility compared to negative small ions in dry air at sea level (American Meteorological Agency, 2012). The values of their mobilities are 1.4×10⁻⁴ms⁻¹per volt m⁻¹ and 1.9×10⁻⁴ms⁻¹per volt cm⁻¹ respectively (American Meteorological Agency, 2012). “The ionization of air or gas creates plasma with conductive properties similar to that of metals” (Zavisa & Shields, 2020). The total air conductivity σ in terms of bipolar ion number concentrations n_+ and n_- is given by equation (1).

$$\sigma = \sigma_+ + \sigma_- = e (\mu_+ n_+ + \mu_- n_-) \quad (1)$$

where μ_+ and μ_- are the average ion mobilities, with σ_+ and σ_- the associated polar conductivities.

“Air conductivity is strongly influenced by aerosol pollution: in aerosol polluted air it is considerably reduced by ion-aerosol attachment” (Dhanorkar & Kamra, 1997). The value of electrical conductivity, according to Coroniti (1961) has an inverse correlation with the nuclei concentration. The mobility of these atmospheric ions is largely affected by their attachment to larger aerosol particles, and this results in a rise in local electric field (Jayaratne & Verma, 2004). Similarly, “in polluted air, the atmospheric electric field (EF) is positively proportional to the aerosol concentration (Z)” (Wang et al., 2018). Harrison (2005) posited that potential gradient and air conductivity have been shown to be related by equation (2), that is Ohm’s law, in aerosol-free and polluted air for a vertical air-Earth conduction current density J_z and PG of magnitude E_z

$$J_z = \sigma E_z \quad (2)$$

Some of the different methods used for measuring potential gradient (PG) include potential probes, burning fuses, water droppers or radioactive probes (Nicoll et al., 2019). Electric field mill is a much faster alternative to low response potential probes (Nicoll et al., 2019).

Effects of atmospheric ions

More so, an increase in aerosol particles has been shown to have a corresponding increase in the Earth's fair weather electric field (Jayaratne & Verma, 2004). High levels of positive air ions pose serious health problems such as heart and lung diseases to humans while negative ions promote the well-being of humans and living organisms, especially in the metabolic process (Kokate, 2015). Spastic attacks induced by positive ions infants have been observed to be terminated by air negative ions (Palti et al., 1966). Lipin et al. (1984) also noted in their study that positive ionization aggravates the bronchial response to exercise. Epidemiological data has shown that elevated “small positive air ionization caused by changes in atmospheric conditions has a direct link with rise in suicide, automobile accident, irritability, depression and interference with the function of the central nervous

system” (Charry & Hawkinshire, 1981). However, studies have shown that negative air ions could help people in relieving symptoms of allergies to dust, mould spores, and other allergens (Jiang, 2018). Kourtidis (2018) reported that “there is emerging evidence that atmospheric electric field (ATEF) variations may interfere with biological processes, including human brain function”.

Conclusion

The effects of atmospheric electricity on the environment and human health have not been fully understood by scientists due to the complex nature of atmospheric electricity and its dynamics, but with more efforts put into experimental studies and data from satellites, these complexities would be surmounted in due course.

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