

The Mechanism of Thunderstorms and its Environmental Effects (A Review)

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DOI: <http://doi.org/10.38177/AJBSR.2022.4308>

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Article Received: 21 May 2022

Article Accepted: 27 August 2022

Article Published: 30 September 2022

ABSTRACT

This study is a review of the mechanism of thunderstorm and its environmental effects. Thunderstorm is a natural phenomenon. Its occurrence in the Earth's atmosphere has been from time immemorial. Thunderstorm has been described as a natural battery as it constitutes both negative and positive parts. This natural phenomenon displays a beautiful signature (lightning) and rumbling noise (thunder) in the sky. Thunder is caused by lightning. The heat energy associated with lightning heats up the surrounding air molecules very fast and causes these air molecules to expand rapidly, and also contract rapidly as it cools off; this rapid expansion and contraction produce sound waves (thunder). The occurrence of thunderstorm is always associated with a great deal of damage to humans, infrastructures, and plants. This damage ranges from loss of lives, collapse of crops and economic trees, infrastructures, especially power grid lines which often threw the affected areas into total darkness. Turbulent weather conditions arising from thunderstorm has a huge negative impact on the aviation industries around the globe, as cases of cancellation of flights are abound and occasional plane crashes. A recent research study has attributed the increasing trend of occurrence of thunderstorm over the continent of Africa to increasing surface temperature; meaning that the continent of Africa will most likely experience more of the devastating effects of thunderstorms. To drastically minimize these negative effects of thunderstorms, accurate prediction of thunderstorms and early warning, keeping to thunder and lightning safety measures, and mitigation of drivers of climate change must be considered.

Keywords: Lightning, Thunderstorms, Environmental effects, Climate change.

1.1. Introduction

Thunderstorm is one of the natural phenomena of the Earth's atmosphere. In some cultures, thunderstorm is attributed to certain things. For example, the Igbos in the South-eastern part of Nigeria refer to god of thunder as 'Amadioha' (Canada: Immigration and Refugee Board of Canada, Nigeria, 2000 August 22). According to Eagleman (1985), Aristotle also made an attempt to explain the concept of thunderstorm as the winds ejected from one cloud to bumped into surrounding clouds. Thunderstorm can be described as a natural battery as it constitutes both positive and negative. Any storm that has thunder and lightning is generally referred to as a thunderstorm (Nugent & DeCou n.d). The formation of lightning is based on the discharge of static electricity in clouds as direct current (Stull, 2017).

According to Stull (2017), "lightning is an electrical discharge (spark) between one part of a cloud and either another part of the same cloud (intracloud (IC) lightning), or a different cloud (cloud-to-cloud (CC)-inter-cloud lightning), or the ground or objects touching the ground (cloud-to-ground (CG) lightning), or the air (cloud-to-air discharge (CA))".

Thunder is caused by lightning. The heat energy associated with lightning heats up the surrounding air molecules very fast and causes these air molecules to expand rapidly, and also contract rapidly as it cools off; this rapid expansion and contraction produce sound waves—thunder (Jensenius, n.d). During lightning, the air surrounding the stream of electrons is heated to about 50,000°F which is three times hotter than the surface of the sun (Brill, 2002 December 30). A recent study has shown that there is an increasing trend of occurrence of thunderstorm over the continent of Africa as a result of increase in surface temperature (Hare & Price, 2020).

1.2. Mechanism of Thunderstorm

Blandchard (1998) stated that moisture, unstable atmosphere, and lifting force (heat) are the three conditions required for the formation of thunderstorm. All thunderstorms go through three stages; the developing stage (cumulus cloud), the mature stage (cumulonimbus), and the dissipating stage (Mogil, 2007). These three stages take an average of 30 minutes to go through, depending on the atmospheric conditions. The energy used in the development of thunderstorms is derived from the release of latent heat during condensation which in turn enables the rising air parcels to remain warmer than its environment as they ascend (ATMO336 Fall, 2020). The daily occurrence of thunderstorms around the globe is said to be more than 40,000 times and about 15 million times in a year (ATMO336 Fall, 2020). There are certain areas of the Earth that experience frequent thunderstorms more than others. Such areas include large landmasses, coastlines, and inter-tropical Convergence Zone (ITCZ) (Geography, n.d). Landmasses are prone to thunderstorms compared to oceans, and more common in tropical areas than the higher latitudes (Met Office, n.d). This is due to formation of free convection as a result of the heating up of the large landmasses (Geography, n.d). It should be recalled that land has a higher thermal conductivity than the ocean. Thunderstorms are classified into three and these are single-cell, multi-cell (squall line), and supercell. And of these three types, supercell generates tornadoes, making it the strongest and most dangerous thunderstorms (Islam & Ryan, 2016).

1.3. Effects of Thunderstorms

Negative Effects: Thunderstorms often times produce precipitation, thunder, lightning, and can be inherently hazardous in many other aspects (Nugent & DeCou, n.d). Hail, flash flood, tornado and downburst are some of the immediate effects of thunderstorms (Rudaux & De Vancoeurs, 1966). Lightning ignition may occur when the electrical current ignites fine fuels on the forest floor” (Latham & Williams, 2001), The discharge of electric charges on the earth’s surface (Callister, 1999). According to Bullock et al. (2018), in the United States, between 75 and 100 Americans are hit and killed by lightning each year. About 2,000 people are killed worldwide by lightning each year (National Geographic, n.d). But as posited by Phippen (2016, June 23), each year, lightning kills about 24,000 people and the victims are mostly the poor. There are reports that thunderstorms increase severe asthma attack due to pollen grains concentration and dispersal of respirable size in the air at ground level (D’Amato et al, 2016). Thunderstorms have been observed to have considerable effect on structures, flights and missiles (Adzhiev et al., 2020). According to Aplicaciones Tecnológicas (2018), factors such as the height of the structure, the frequency at which the lightning strikes occur in an area, and the presence of higher elements determine the risk of a lightning striking on a building. More so, intense thunderstorms disrupt telephone service and radio communications, and also cause *short circuit damage in buildings and vehicles* (Environmental Services Division of Public Works, City of Superior, 2020). *It was also reported that infrastructure worth over \$11 million were destroyed in east-central Minnesota and Northwest Wisconsin from massive flooding within 24 hours due multiple rounds of strong to severe thunderstorms in June 11-12, 2016* (Environmental Services Division of Public Works, City of Superior, 2020). “Large diameter hailstones can cause severe damage to crops, tree foliage” (Stull, 2017). “Lightning caused about 30% of the 8,000 forest fires in Canada in the 1990s, but these lightning-induced fires accounted for about 85% of the 2.8 million annual area burned” (Kochtubajda et al., 2019).

Positive Effects: However, thunderstorms have some positive effect on the environment such as production of nitrates in the soil for plants' use. This is made possible by the splitting nitrogen molecules by lightning which in turn react with oxygen in the atmosphere to form nitrogen (iv) oxides that dissolve in rain to form nitrates in the soil. Thunderstorms similarly produce cooling effect on the earth's surface and induce the transportation of particles and pollutants from the tropospheric layer of the atmosphere to the stratospheric layer (Hamwell, 1980). Scientists have reported the production of ozone by summer lightning over the United States (NASA/Goddard Space Flight Center, 2003 March 20). This ozone acts as a cleansing agent by removing atmospheric pathogens (Pudykiewicz, 2020).

1.4. Thunderstorms Prediction Challenges

Thunderstorm is said to be difficult to predict because their inherent small size and correspondingly limited intrinsic predictability (Bouttier & Marchal, 2020). The difficulty is also due to the fact that thunderstorms are accompanied by heavy rain, tornadoes, and large hail. More so, studies have shown that "the hour level weather forecasting usually does not provide timely and accurate weather parameters for early warning, especially during rainstorm" (Chao, 2018). Current technology, according to Mulu and Enyew 2018) cannot provide reliable long-term prediction of thunderstorms for aviation operation. The World Meteorological Organization (2017) posited that the need for dense observation networks of wind, temperature and moisture, insufficient dedicated computer power for nowcasting in operational centers and rapidly growing model errors at convection-permitting scales are the three primary obstacles to overcome for Numerical Weather Prediction (NWP) to provide high-resolution nowcasts of severe weather. All these difficulties are not unconnected to the challenges faced by aviation industries. And some of these reasons were also noted by Al-Jundi et al. (2017) as "major challenges for efficient flight planning and air traffic management., and stressed that inaccurate forecasting of weather poses a great danger to aviation".

1.5. Thunderstorms and Lightning Safety Strategies

To guide against injuries and fatalities associated with thunderstorms, there are certain safety measures that must be considered. It is important that one seeks safer areas such as large structure with plumbing and electrical wiring and avoid being in contact with any conducting materials (Zimmermann et al., 2002). Water bodies (ocean, rivers etc), isolated objects, high ground (mountains and hills), and outdoor activities must be avoided during thunderstorms (National and Atmospheric Administration (NOAA), n.d). Corded telephones like landlines phones should be avoided during thunderstorms (Althaus, 2006). Electrical appliances and electronics should be unplugged before thunderstorms, because unplugging any of these during thunderstorms is dangerous (Bradford, 2019 March 1). Finally, 30/30 safety lightning rule should be observed and also avoid lying flat on the floor during thunderstorms.

1.6. Conclusion

In conclusion, the need to ensure the safety of the people, efficient flight planning and air traffic management cannot be over emphasized. Therefore, **improving weather forecasts and timely warning will in no small measure increase the safety levels and** efficient flight planning and air traffic management. This can only be possible by efficient deployment of AI and machine learning, and proper atmospheric modelling. For instance, preliminary case study

by Gupta et al. (2002) as shown that precipitation fore-casting could be significantly improved by a proper synthesis of remotely sensed information with regional atmospheric modelling.

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare no competing financial, professional, and personal interests.

Consent for publication

Authors declare that they consented for the publication of this study.

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