EFFECT OF MAGNETIC FIELD ON CHARGED WATER VAPOUR IN MOTION

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ABSTRACT

Drought and flooding are worldwide problems. The traditional methods of solving them lack efficiency. To proffer informative framework for solving these problems, this study developed laboratory experiments that investigated the effect of magnetic field on charged water vapour. During the experiment, charged and uncharged condensed droplets generated inside cloud chamber were focused with magnetic field $\boldsymbol{B}$ from stacked solenoid system and permanent magnet. These were enclosed inside a calorimetric cupboard of about 120 ℃. Results obtained showed that uncharged water vapour remained cloudy inside the chamber for about 121 s before the production of droplets of diameter D_C << 1.0 mm that coalesced in about 362 s with diameter $D_N \leq$ 2.0 mm after 1200 s of magnetic interaction. Prior to condensation, the cloudiness of charged vapour lasted for about 6 s, coalesced in about 35 s with $D_C \cong 1.0 - 4.0\ mm$ and $D_N \cong 2.0 - 5.0\ mm$.

Keywords: Calorimetric cupboard, Magnetic interaction, Charged cloud droplet and Coalesced droplet.

INTRODUCTION

Flood occurs when water bodies, soil and vegetation cannot absorb all the precipitated water. The peak discharge of a flood is influenced by factors such as the intensity and conditions preceding storms (www.cdc.gov.flood, 2008). Flood disaster killed over three hundred people in 1980 and destroyed properties worth millions of Naira in Ibadan (Tomori, 2011). In 1998, Bangladesh experienced major flooding in which two third of the country was under water and if this persists, coastal cities may experience constant flooding in 2100 (Jamie et.al, 2005).

A drought is an extended period of months when a region is deficient in its water supply due to inadequate precipitation. The ten most severe droughts since 1980 have caused over $144 billion damages according to the National Oceanic and Atmospheric Administration (Eden, 2011). Also, recent reports by the United Nations indicated that about one third of the world population will live under severe water stresses by the middle of this century. Consequently, water managers have being exploring precipitation enhancement via cloud seeding as alternative to augment water resources (Bruintjes, 2010).

Seeding of clouds require that the atmosphere contains supercooled liquid. But, most areas with problems of drought do not have precipitable rain cloud within their tropospheric domain. Thus, means of shifting the excessively precipitating charged rain cloud to location where drought is being experienced is needed. Hence, this study.

Atmospheric Rain Cloud

Evaporation of water molecules requires the release of latent heat that results in the cooling of the earth's surface and drives the updrafts in clouds. Cloud droplets can be produced on nucleation of an insoluble hydrophilic or hydrophobic surface. The surface tensions F_S due to vapour, liquid and substrate, must balance the mechanical equilibrium along the line that is common to the three phases. The mechanical equilibrium is expressed as

$$\delta_{CL} + \delta_{LV} \cos\emptyset = \delta_{VC}, \qquad (1.1)$$

where, δ_{CL} is F_S associated with nucleating surface and liquid phase, δ_{LV} is F_S associated with the liquid-vapour interface,δ_{VC} is F_S associated with vapour phase and nucleating surface, and $\emptyset$ is the contact angle (Byers, 1965).

Clouds are generators of static charges. Collision-coalescence process that occurs in warm clouds are facilitated by cloud's formation mechanisms such as orographic uplift, convergence lifting and radiative cooling. As cloud droplets form within clouds, they become electrically charged (Gunn, 1952). Experimentally, average charges on cloud droplets in layer clouds have been measured using absolute filter electrometer (TSI Model 3068). The quantity N of the droplets were estimated with condensation nucleus counter (TSI Model 3700) and average charge q on cloud drops was calculated (Kenneth *et.al*, 2004) from

$$q = \frac{I}{FN}, \qquad (1.2)$$

where I is the electrometer current (fCs^{-1}) and F is the electrometer flow rate ($cm^3\ s^{-1}$). Similarly, United Arab Emirates installed network of negative ion generators in the desert that released clouds of negatively charged ions. The charged ions rose in the hot air, attracted water vapour molecules (dipolar molecules) (David *et.al.*, 2011).The ionized vapour condensed, aggregated and precipitated (facilitated by gravitational force F_g**)** as rainstorms.

The Experimental Procedures

A cloud chamber (inserted with spiral Al-Cu electrodes and powered by line transformer T_L circuit $V_0 \geq 1.98\ kV$) was constructed from pyrex glass tube and placed inside a constructed calorimetric cupboard. The cupboard was maintained at a temperature T_C of about 100 ℃ to ensure that condensation of water vapour is not caused by surface temperature and other likely atmospheric condensation nuclei. Water vapour was generated and charged using; ionization effect of N_2 gas and induction effect of Al/Cu electrodes. The set-up for charged and uncharged cloud droplets (shown in Appendix A1) were investigated with permanent magnet and bored-centered solenoid having magnetic flux density B of about $165.23\ mT$, for reactional period of 1200 s. To monitor increase/decrease in the number of condensed charged droplets, the surface of the chamber was sampled with circle of radius 2.5 cm. Results obtained were compiled and presented.

Responses of Cloud Droplets

Aggregation of condensed vapour with diameter range of 0.2 cm and 0.6 cm were observed during transverse focusing of magnetic field on the cloud chamber inside the calorimetric cupboard. Variation in responses of charged and uncharged water vapour when projected with magnetic fields from permanent and solenoid system are presented in Table 1.1. The number of condensed droplets N_C (per sampled area on cloud chamber) reduced in number after coalescence and nucleation (plotted in Figure 1.2) while, the droplets showed increase in diameter as shown in Table 1.1.

Motion of condensed charged cloud droplet

The charged coalesced droplets displayed coalescence and downward movement along the glass wall. The downward movement (trajectory per droplet) is computed and shown in Figure 1.3 using; the radius r(mm) of droplet's deflection, magnitudes of electric field E (V/m), magnetic flux density B(T) and magnetic force F(N) of solenoid's field. These are expressed as;

$$|F| = \left(\frac{I^2}{2}\right) \cdot \frac{dL}{dx}, \qquad (1.3)$$

$$L = \left(\frac{\mu_0 \mu_r N I}{B}\right), \qquad (1.4)$$

Table 1.1: Comparative results on responses of generated Cloud Droplets

S/N	Observable Variable of Water Vapour	Responses of uncharged Water Vapour	Responses of charged Water Vapour in the presence of Permanent Magnet	Responses of charged Water Vapour in the presence of Solenoid System
1	Period of cloudiness of chamber after vapour's inlet.	121.0 seconds	6.0 seconds	14.0 seconds
2	Diameter of deflected and condensed water vapour after chamber's cloudiness.	D_C< 1.0 mm	D_C = 2.0 mm - 4.0 mm	D_C =1.0 mm - 4.0 mm
3	Region in the chamber's wall where deflected water vapour firstly condensed /coalesced.	Simultaneously, almost every part of the chamber	Focusing region of the permanent magnet on the glass's wall	Slightly faster at the focusing region (inside the glass's wall) of the solenoid system
4	Ranges of induced charges' potential difference observed during the charging	0.00 mV	0.6 mV - 197.5 mV	0.4 mV - 195.8 mV
5	Time of coalescence of condensed vapour.	362 seconds	35 seconds	49 seconds
6	Diameter of condensed vapour after coalescence.	D_N < 2.0 mm	D_N = 2.0 mm - 4.0 mm	D_N =2.0 mm - 4.0 mm
8	Size of coalesced droplet at 20th minute.	D_N =≤ 2.0 mm	D_N = 2.0 mm - 5.0 mm	D_N = 2.0 mm - 5.0 mm

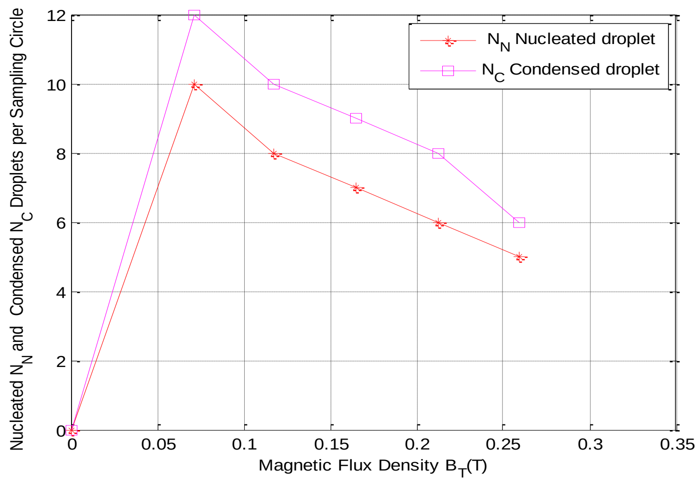

Figure 1.2: Response of N_N and N_C with magnetic flux density B.

$$r = \left(\frac{E \cdot t}{B}\right), \qquad (1.5)$$

where L is inductance (mH) of the solenoid's coil, x is magnetic distance (mm), I is current (A), N is the number of turns of Cu coil, t(s) is the period of magnetic interaction, μ_0 is the permittivity of free space and μ_r is the relative permittivity of the core.

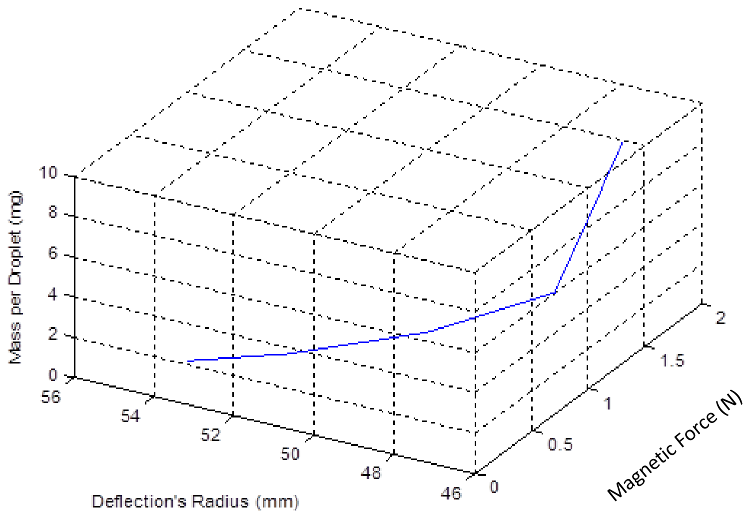

Figure 1.3: 3-D trajectory of charged coalesced droplet (per droplet)

CONCLUSION

The magnetic forces utilized during the experiments caused the coalescence and nucleation of charged cloud droplets in few seconds during interaction. This effect facilitated the increase in diameter, reduction in the number of condensed charged droplets and; downward movements of coalesced droplets, which was aided by gravitational force F_g.

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Appendix A1: Set-up of calorimetric cupboard.