Physical Mechanism of Sediment Education in Heatclouds

Alaa H. Kamil

College of Science

University of Misan

Misan, Iraq

Alaahusein5@uomisan.edu.iq

Iqbal H. Abdulkareem

Environment Research and studies center University of Babylon ,Iraq

doraqbl@yahoo.com

Qasim S. Kadhim

College of Basic Education

University of Babylon

Babil, Iraq

basic.qasim.shakir@uobabylon.edu.iq

Abstract

The article discusses the mechanism of precipitation in warm clouds under the influence of the energy of instability of electrical origin. The question of the influence of electric forces on the enlargement of drops arose in connection with the explanation of the formation of precipitation in warm clouds.

Introduction

The basis of the modern theory of the mechanism of sedimentation in the clouds is based on postulates developed in the classical theory of the formation of Wegener – Bergeron – Findisen precipitation. This theory is universal for mixed clouds consisting of three phases of water in the atmosphere. The theory is based on the formation of precipitation due to phase transitions of water and gravitational coagulation of droplets. A necessary condition for the formation of precipitation is the formation of a solid phase of water (ice crystals) and the further growth of hydrometeors due to differences in the saturation elasticity over water and ice, which reaches a maximum at a temperature of –12 ° C. As a result of the appearance of ice crystals, the process of redistribution of water vapor from evaporating cloudy water droplets to ice crystals, which, coarsening to the size of precipitation particles, fall to the earth's surface, occurs. The theoretical foundations of precipitation formation formulated in are the physical basis for modern AB methods for supercooled cloud systems[1]. The disadvantage of the classical theory is the absence of substantiation of the formation of precipitation in warm clouds. The results of the aircraft sounding of the atmosphere showed that precipitation is formed not only in the presence of mixed cloud layers with supercooled droplets and a solid phase but also in the presence of liquid-drop supercooled clouds and clouds located in the zone of positive temperatures. Submitted by aircraft sensing [2].on average fora year precipitation falls out of clouds of a mixed-phase - 46%, from water clouds - 36%, from pure ice - 18%. SedimentThe clouds of a mixed structure are alternating layers of different phases. In summer, the probability of precipitation from water clouds increases to 62%, in winter it decreases to 26%. This confirms the hypothesis of a variety of mechanisms. sedimentation, but leaves some issues that have not been sufficiently studied and studied, in particular, the processes enlargement of cloud drops to the size of precipitation in warm clouds. The article discusses the mechanism of precipitation in warm clouds under the influence of the energy of instability of electrical origin. The question of the influence of electric forces on the enlargement of drops arose in connection with the explanation of the formation of precipitation in warm clouds.

The formation of cloud drops

The foundations of the theory of condensation growth and evaporation of droplets were developed by Maxwell in the 19th century and with clarificationsStefan and Sreznevsky apply so far [3].At the level of condensation in rising air, The formation of cloud droplets with an average radius of 1-2 μkm is observed. The formation of these droplets during the condensation of water vapor on condensation nuclei, as a rule, electrically charged occurs in a fraction of a second[4]. With the advent of cloud droplets, a redistribution of thermal energy occurs throughout the entire volume of cloud formation. The cloud receives most of the heat due to the released latent heat of condensation. The warmed cloud air acquires additional lift and rises until it cools down the wet adiabat until saturation is again reached and the next portion of the steam condenses on the already existing and newly formed droplets. Due to the absence of other mechanisms drops can grow up to 5-8μkm. Subsequently, the growth slows down significantly, and an increase in the size of the droplets to radii of 18–20 μkm is from 1 h to 7.5 h [5.6]. This does not correspond to the formation of precipitation in the convective cloud. The formation of precipitation particles is naturally developing warm convective clouds occurs during the lifetime of the convective cell ~ 30 min [7]. Another experimental fact that requires an explanation is that the number of small droplets formed in the lower layer of the cloud decreases with height, and the sizes of the droplets increase. Of all the physical mechanisms that lead to the enlargement of cloud elements, gravitational coagulation is currently generally recognized due to the difference in the speeds of fall under the influence of gravity. The critical value of the droplet radius at which gravitational coagulation begins is 18–20 μkm. Further explanations are needed to explain the enlargement of droplets in the range from 8 to 18–20 μkm. Experimental model [8].shows that the droplets do not grow when falling, but when rising in an upward flow. Hydrodynamic forces occur when the droplet size reaches a radius of 2.5 mm. Observations show that droplets with a radius of more than 2.5-3.2 mm do not occur - they flatten and collapse, forming a large number of smaller droplets [3]. In laboratory experiments, such droplets with a diameter of more than 2.5 mm are sprayed over a very short period. For droplets 4.25–6.25 mm falling in calm air, the number of splashes from laboratory measurements ranges from 3 to 97 (30–40 on average). When spraying, a few drops with a radius of about 1 mm and a relatively large number of small charged drops are formed as a result of the ball electric effect [4]. Large drops fall in the form of rain or rain, while small drops rise in an upward flow to the top of the cloud, becoming larger to critical sizes. Such a chain reaction can occur from 3 to 6 times with a gradual attenuation as the water content is washed out [3]. This process takes place in time to 30 minutes.

Influence of electrical forces on the enlargement of cloud drops

In the classic paper, T. Bergeron considered the following precipitation factors: 1) electric forces of attraction of oppositely charged cloud drops or drops with induced charges in the electric field of the earth; 2) hydrodynamic forces; 3) the difference between capillary and hygroscopic forces on the surface of the droplets; 4) the temperature difference between warm and cold drops; 5) the effect of turbulence. However, T. Bergeron concluded that the listed mechanisms are not effective in sedimentation [9].Experimental studies conducted by different authors [9,10,11,12] showed that the effect of electrical forces on the coagulation of droplets can be significant. Experiments N.A. Wager [13] revealed the existence of a positive effect by the deposition of artificial fog with charged water droplets. In an artificial fog that remains in the chamber of fogs for more than 2 hours, when exposed to electrified small droplets of water, its transparency rapidly changed.The density of negative charges of water drops was ~ 2.5 10^{-4}

C / kg, positive ~ 5 10^{-4} C / kg. When considering the growth of cloud droplets in the specified size range, V.M. Muchnik [9]. concluded that droplet charges should be taken into account. The movement of particles in a cloud occurs under the action of gravity, friction force, the Coulomb force of electrostatic interaction, the force of the electric field of the polarization of a drop under the action of the electric field of the Earth, the force of attraction as a result of induction of opposite chargesMeasurements of the charges of cloud particles directly in the clouds showed that 90% of all droplets are charged [14]. Adsorption of ions, phase transitions of water, destruction of particles, and other factors lead to the formation of electric charges on cloud particles. Ions of both signs are always present in the atmosphere since ion formation occurs continuously. Based on an experimental study of the effectiveness of collisions of uncharged droplets of similar size, we can assume that collisions are more elastic and do not lead to a merger [9]. The presence of an electric charge, reducing the surface tension, promotes the formation of a connecting channel between the droplets. The formation of the connecting channel occurs at a potential applied to a droplet less than 10 V. Similar potentials correspond to the charges of cloud and raindrops. The charge of small cloud droplets is less than 10^{-15} C; charges large drops on average 10^{-8} - 10^{-7}C. For drops with a radius of 10 μkm, the limiting charge is ~ 3 • 10^{-14} K. According to the conclusion of I.M. Name-Nitova [10], the efficiency of the confluence of the colliding droplets substantially depends on the electric field strength and the magnitude of the charges on the droplets. Laboratory measurements show that a change in field strength from 0 to 15 V / cm increases the efficiency of coalescence of large droplets by more than three times [14, 15]. Field strengths in cumulus clouds are most often 1-5 V / cm [9].It was shown theoretically in [11, 16] that the charges of droplets affect their coagulation in the size range of less than 30 μkm. It follows from the calculations that in the case of opposite charges of droplets, coagulation is enhanced by the forces of electrical interaction. In the presence of a charge on a large droplet and its absence on smaller coagulation, the formation of an induced charge on a smaller droplet contributes. In the case of collisions of sufficiently large droplets, the role of electrical forces increases significantly, as a result, the merging of droplets becomes more efficient. The variety of electrification mechanisms has different significance at different periods of cloud growth and under different conditions. The electricity of clouds can be both a consequence and a cause of phase and structural transformations of water in the atmosphere. For the first time to consider the energy of the instability of electrical origin suggested IM Imyanitov [10], who believed that along with the energies of thermodynamics, phase and colloidal instability, in clouds, under certain circumstances, the energy of instability of electrical origin can actively manifest itself. In what particular processes this energy can manifest, no refinements have been made, however, the author saw the possibilities of effective intervention in atmospheric electrical processes with relatively low energy available to people.The manifestation of the energy of instability of electrical origin is advisable to represent in the form of micro-instability energy of the first type, which occurs when the Rayleigh limit and the second type reach, macro-instability, which manifests itself in lightning discharges when electricity is accumulated in certain volumes of a convective cloud [6]. The cause of the manifestation of the electric energy of instability is the structure of the water molecule in the form of a dipole. The effect of the micro-instability of the electric forces manifests itself when the Rayleigh limit is reached by small drops [17] as a result of the splashing effect and with the ball electric effect, which is observed only in dipole fluids. The main cause of the effect is the presence on the liquid surface of a layer of oriented dipoles, which create an electric double layer. The electric field of the dipoles extends to a certain depth inside the liquid and concentrates free charges near its boundaries.(Fig. 1) shows the structural diagram of the water molecule, hydrogen bonds between the complexes of water molecules and a water drop under a microscope, clearly visible are separate associated clusters of water molecules and voids between them. Practically, water molecules with “dense packing in a drop” occupy only 0.53 of the area and 0.38 of the volume of the total mass of water.An additional restriction is imposed on the absorption of ions (electrons) by a drop, called the Rayleigh limit [17]. It is known that a charged drop will evaporate until the external electric field force on the surface of the drop exceeds the internal force of its surface tension. Then, due to the proximity of the charges of one sign, the drop will break apart, forming several smaller droplets. Since the positive charges are on the surface of the droplet, during downward motions they evaporate and form a positive volume charge. The scattered parts of the drop as a result of reaching the Rayleigh limit have a negative charge and form a correspondingly negative space charge. These processes occur in the central part of the cloud. Experimentally, the process of increasing charges was discovered by V.A. Zaitsev [8], who believed that in the center of the cloud there is an ionization source. For droplets of various sizes, the possible values of the limiting charges and the Rayleigh limits are given in Table 1 [17].

Table 1

The limit number of elementary charges on a particle

Limit	**Particle diameter μkm**		
	0.01	**1.0**	**100**
Ionic	$3.47 \cdot 10^2$	$3.47 \cdot 10^6$	$3.47 \cdot 10^{10}$
Electronic	$1.72 \cdot 10$	$1.72 \cdot 10^5$	$1.72 \cdot 10^9$
Rayleigh Limit	$4.45 \cdot 10$	$4.45 \cdot 10^4$	$4.45 \cdot 10^7$

The maximum number of ions and electrons for a droplet with a diameter of 100 μkm is $3.47 \cdot 10^{10}$ and $1.72 \cdot 10^9$, respectively stately. For comparison, the raindrop with a diameter of 10 mm in a thunderstorm is about $4 \cdot 10^8$ elementary charges, which is 1% of the maximum charge [17]. In evaporating droplets, the Rayleigh limit decreases with decreasing drop size. Therefore, for droplets that can evaporate, the diameter will decrease until it is 0.01 μkm. Not evaporated drops are adsorbed by larger drops, increasing their size.

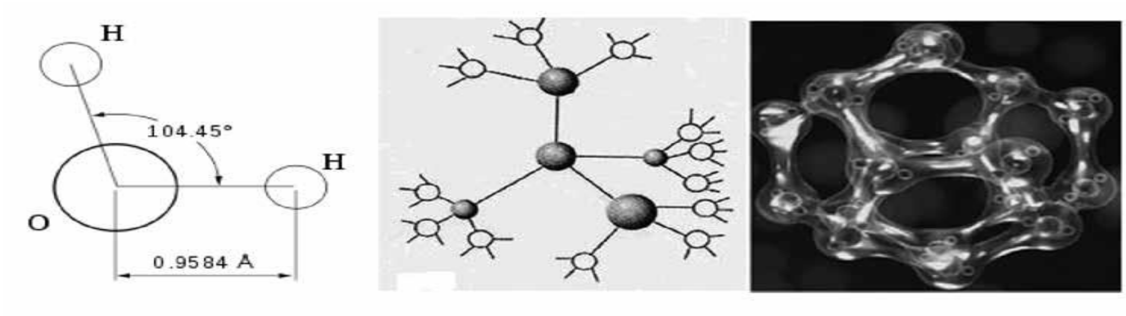

Fig. 1. Type of molecule (www.wikipedia.org) and hydrogen bonds of a structured drop of water under a microscope (photo by Masaru Emoto)

The theory of electrification when spraying drops was developed by J. Mason [4] and other researchers. Convective clouds, from which precipitation does not fall out, observed during the warm period of the year, are a colloidal stable system. The process of transition of powerful convective clouds from a state of colloid-stable to colloidal far-unstable with precipitation can occur naturally or artificially induced. For warm convective clouds, to cause precipitation, it is necessary to stimulate the growth of cloud droplets to the size of precipitation. To estimate the forces acting between charged drops, it was necessary to solve the problem of the interaction of charged drops in an external electric field [9]. A more complete and accurate solution of the equation of motion of two drops of different radius and charge, when both particles are charged with opposite charges, when one of the particles is not charged and when the particles move in a uniform electric field, decided LM Levin [16], having received the expression for the coefficient capture E. He theoretically showed that even relatively small charges lead to electrocoagulation of cloud droplets with a diameter of 1-30μkm

Experimental data

Drop structure of a convective cloud based on experimental data V.A. Zaitsev [8] and generalized data on the distribution of water content, size and the number of droplets of a powerful cumulus cloud are shown in Fig. 2 [8]. Four zones are distinguished in the cloud, the largest drops are located in the central part of the cloud.

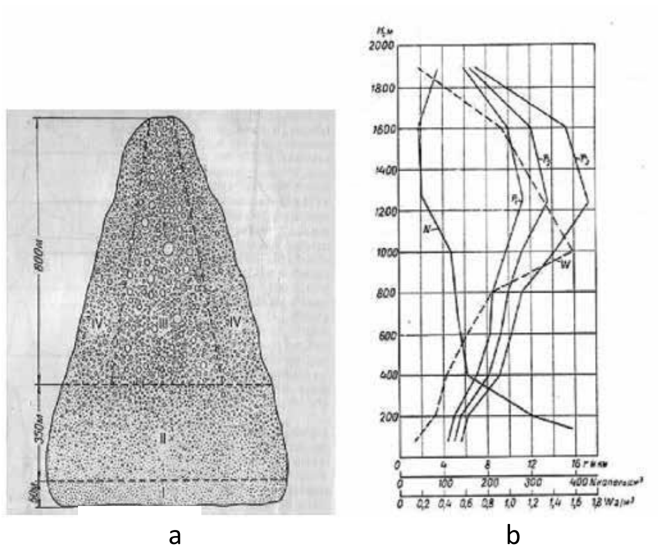

Fig. 2: a) Diagram of the distribution of droplets in a warm cumulus cloud; b) The average distribution of water content (W), size (r)and the number of drops (N) in Cu Cong with a capacity of 2000 m [8]

Zone I at the base of the cloud (~ 50 m) refers to the level of condensation. In this zone, most of the droplets (65%) have sizes from 4 to 8 μkm. The drops formed in this zone rise in an upward flow upwards, and in their place, new drops are formed. In zone II (~ 50-400 m) most of the droplets (60%) have sizes from 6 to 14 microns, the maximum diameter of the droplets does not exceed 50 μkm. Zone III, which occupies the central region of the cloud, is located on average from a height of 400 m above the base of the cloud to its top. In this zone, 60% of all droplets have a diameter of 8 to 18 μkm, the largest droplet size is 100-300 μkm, individual droplets reach 300-400 μkm and more. The presence of large droplets in the center of a convective cloud indicates the growth of droplets in the upward flow due to micro electric instability. Zone IV is located at the edges of the convective cloud and is 50–100 m thick, the dominant droplets are 8–14 μkm, and there are no large droplets. The drops shown in Fig. 2 in zone III have sizes from 8–18 μkm to 100–400 μkm in diameter. The main mass of cloudy water in continental clouds is contained in drops with a radius from 3-4 to 20-30 μkm. The concentration of such drops is 10^2 - 10^3 cm^3. Vertical movements inside the cloud have the character of individual jets and thermals. According to the measurements of V.A. Zaitsev [8], the area of ascending jets with a vertical speed of ~ 5 m / s in various clouds constitutes 20–35% of the total cross-sectional area of the middle part of the cloud. The maximum speed of ascending flows in Cu cong with a capacity of 3-4 km reaches 10-11 m / s. The descending flows in these clouds occupy from 50 to 65% of the area mainly at the periphery of the cloud and have a speed of about 2 m / s. At the same time, zones are observed that occupy up to 15% of the area, where the vertical motions are practically zero. Consequently, a powerful cumulus cloud is prepared for precipitation. The transition to cumulonimbus will depend on the magnitude of the energy of instability and moisture content of the atmosphere.

Conclusion

Analysis of previously performed experiments and theoretical studies carried out by various authors [8, 9, 16, etc.] showed that the growth of cloud droplets in a warm convective cloud occurs in ascending flows due to electrocoagulation as a result of electrical micro-instability of droplets when they reach the Rayleigh limit. Growing droplets reach their maximum at the top of the cloud. The cloud at the development stage is positively charged since the negative ions are spent on the formation of cloud drops. As a result of the evaporation of positive ions from the droplet surface, a positive space charge is amplified in the cloud during descending motions, and a negative space charge is formed below it. Negatively charged small droplets in the upward stream are absorbed by larger ones, increasing their size. Coagulation of positively charged droplets with negatively charged and induction processes are integral parts of the sedimentation mechanism. During the cascade process of the formation of a convective cloud, a layered structure of space charges and large droplets forming precipitates will be observed.

References

1. Bergeron T. On the physics of clouds and precipitation.// Proc. Conf. Int. Union Geodesy and Geophysics, Lisbon, - Part II. - 1933-p. 156 - 178.
2.Dubrovina L.S. Clouds and precipitation according to aircraft sounding. L .: Hydrometeoizdat. – 1982-216 p.
3. Matveyev L.T. The course of general meteorology. Physics of the atmosphere. L .: Hydrometeoizdat. - 1984. - 640 p.
4. Mason B. J. Physics of clouds. / / L .: Hydrometeoizdat. - 1961-541 p.
5.Kozlov V.N., Klingo V.V. Theoretical substantiation of a generation of a charged hygroscopic reagent for artificially inducing precipitation from clouds // Trudy GGO. - Vol. 565. - 2012-C. 216-231.
6.Kozlov V.N., Emelyanova N.A., Kite N.A. Artificial regulation of precipitation.- Saarbrucken Deutschland. - Ed .: LFP LAMBERT Academic Publishing. - ISBN: - 2013-372c. ISBN: 978-3-659-46160-6
7. Mazin I.P., Schmeter S.M. Clouds The structure and physics of education. / / L .: Gidrometeoizdat. -1983- 279 p
8.Zaitsev, VA, Ledokhovich, A.A. (1970) Instruments for studying fogs, clouds, and measuring humidity. - L .: Hydrometeoizdat. - 255s.
9. Muchnik V.M. Physics of thunderstorms. - L .: Hydrometeoizdat. - 1974-351 s.
10. Imyanitov I.M., NikandrovV.Ya. On the possibility of influencing the electrical processes in the clouds // Short texts and abstracts of the reports to the meeting on the active impacts on clouds and fogs. - L .: Izd. GGO .- 1965 - P.138-142.
11. Smirnov V.V. On the effects on clouds using charged particles. // Tr. IEM - Issue 2 (36). - 1972- p. 3-32.
12.Shishkin N.S. Clouds, precipitation and thunderstorm electricity. - L .: Hydrometeoizdat. 1964–402 s.
13.Vager I.A. Laboratory experiments precipitation of mist dispersed electrified water. / / Tr. NRU GUGMS. - Ser. 1.- Issue 1.- 1941-C.174-180 14.Mordovia, LS, On Charging of Cloud Particles, / / Tr. Ggo. - Vol. 242. - 1969-C.

94-103.
15. Tverskaya N.P. Experimental study of the collision and merger of charged drops. / / Tr. Ggo. - Issue 73. - 1958- p. 123-131
16. Levin, LM Electrical coagulation of cloud droplets. / / Tr. Elbrus Highland Expedition. - T.2 (5). - 1961 - p. 542.
17. Raist P. Aerosols. M .: Mir. - 1987-278c.