ABOUT THE ORIGIN AND RECURRENTCE OF THE LIGHTNING OF THE CATATUMBO RIVER

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Resumen

Al sur del lago de Maracaibo ocurre desde tiempos remotos un relámpago recurrente, incluso en épocas de sequía, denominado "Faro de Maracaibo" o "Relámpago del Catatumbo". Diversas hipótesis se han conjeturado para explicar el carácter localizado, recurrente y antiguo del fenómeno, siendo motivo de controversia su completa comprensión. Se presentan los resultados de las expediciones realizadas para ubicar los epicentros y caracterizar el fenómeno. Adicionalmente se discute un modelo microfísico fundamentado en la presencia del gas metano como agente causal de la actividad eléctrica atmosférica.
Palabras Clave: Relámpago del Catatumbo, Electricidad Atmosférica.

Abstract

To the south of the Maracaibo Lake (Venezuela) it happens from remote times a recurrent lightning, even in dry seasons, denominated Maracaibo Lighthouse or Catatumbo Lightning. Diverse hypothesis has been surmised to explain the located character, recurrent and old of the phenomenon, being reason of controversy its complete understanding. The results of the expeditions are presented carried out with the purpose of to locate the epicenters and to characterize the phenomenon physically. Additionally a microphysics model is discussed; this model is based in the methane gas like causal agent of the atmospheric electric activity.
Keywords: Lightning of the Catatumbo, Atmospheric Electricity.

1 Introduction

The manifestations of the such atmospheric electric activity as the lightnings and the rays are common in the whole region of the Venezuelan southwest, but concretely in the region of the deltas of the rivers Catatumbo and Bravo, to the south of the lake of Maracaibo. Standing out among such meteors the persistent occurrence of a deaf lightning, well known as the "Lightning of the Catatumbo" or "Lighthouse of Maracaibo". The radiance and brightness of this phenomenon is such that it can be appreciated from Maracaibo city and even to hundreds of kilometers of distance, in the Venezuelan Andes, the Magdalena River in Colombia and in the Caribbean Sea, during almost all the year [1].

The occurrence area of the "Lightning of the Catatumbo", it doesn't vary from their first mention written in 1597 when Lope de Vega mentions its in the epic poem "La Drangontea" [2]. Diverse authors have reported the occurrence of the "Lightning of the Catatumbo" from last century to now: the naturalistic Alexander von Humboldt describes the phenomenon like "... electric explosions that are as phosphorescent radiances…" [3] and the geographer Agustin Codazzi points out its "as a continuous lightning" that seems to arise in the marshy region of the river Zulia and its surroundings, to the south of the Lake of Maracaibo. Standing out for their continuous persistence in position and time, for almost every night of the year, even in the period of drought, deriving of there the name of

"Lighthouse of Maracaibo" [4], at the end of last century Hann points out its, in the Climatological World Catalogue. Recently Zavrotsky [5] it has reported its occurrence and phenomenology; without attempting a physical model that explains the nature of the permanent and located electric activity that it constitutes the essence of the considered atmospheric phenomenon.

Consent doesn't exist around the causal mechanism neither on the location of the or of the epicenters, mainly because the occurrence region is an inhospitable area of 226.000 hectares of swamps, almost permanently flooded with abundant cloudy and pluvious during all the year, that conform the "Park National Ciénagas de Juan Manuel."

The first modern intent of characterizing the phenomenology of the "Lightning of the Catatumbo" Melchor Centeno carried out it [1] who carries out a geographical and climatic focus of the same one and it defines the occurrence region to the area understood among the coordinates 8º 15' and 10º north latitude, and among the 4º 45' and the 6º longitude west. Centeno attributes this way the origin to the permanent electric storms caused by the closed circulation of winds in the region, without discarding the possibility of the existence of some causal agent in the underground, such as geothermal, geomagnetic or radioactive sources.

The second systematic study of the "Lightning of the Catatumbo", were carried out in 1966 by Andrés Zavrostky and collaborators of the University of The Andes [7]. It consisted on three expeditions, without penetrating in the marshes, and it was limited to the observation from the urban centers of "Los Encontrados" and Santa Barbara, and/or adjacent points of the highway that both populations unite, concluding that the cause of the phenomenon "presumably it is kind of a permanent storm in certain region of Venezuela of essentially electric nature between the loaded clouds with electricity and certain permanent load in the floor... in the Gran Ciénaga to the west of the Maracaibo Lake."

The stormy activity and the existence of certain superficial electric load don't explain the old and located character of the phenomenon neither the physical mechanism responsible for the phosphorescence (lightning) that accompanies the occurrence of the rays, as neither gives bill of the permanent intermittence that characterizes it even in dry seasons.

On the other hand, to postulate the existence of permanent electric storms as cause of the phenomenon requires of a microphysics study of the atmospheric processes that gives bill of the mechanisms of separation of loads in clouds of storms, and also, the subsequent discharge of rays supposes to specify the conditions for the existence of an intense superficial and local electric field as causal agent of the discharges cloud-earth during the electric storms. From a theoretical perspective, the elaboration of models for the study of the atmospheric electricity and the stability in ionized gases is still a free problem in physical meteorology [8].

The study of the "Lightning of the Catatumbo" could contribute to the understanding of the microclimate in the region and also have, practical applications for the agro industry. The purpose of this work is to present a possible mechanism that explains the characteristics of the "Lightning of the Catatumbo", as well as the identification of the causal and co-causal agents of the phenomenon, with a micro and macro physical focus.

The presented pattern could be used for the understanding of other geographical regions of prominent electric activity in tropical and subtropical regions, like it is the case of the South of Florida in USA. For they stand out it the conditions of their occurrence and the phenomenology (section 2) observed during the expeditions carried out to the interior of the marshes during the biennium 1998-1999 for Falcon and collaborators [9], then a model is presented based on the atmospheric microphysics (section 3) and, finally, its explanatory consequences and the list of the Methane like causal agent of the unusual

observed atmospheric electric activity are discussed [10-12].

2. Generalities.

The extensive region of about 226.000 hectares to the south-west of the lake of Maracaibo, it is defined to the north by the basin of the Santa Ana river and to the south for the Catatumbo river, for the west the regional highway #6 that it unites the populations of Machiques with Casigua El Cubo and for the east the deltas of the mentioned rivers that they pour their waters in the Lake of Maracaibo. Embrace in its interior to the Bravo river, from its birth until their outlet, the Concepción river, the marshes of Juan Manuel de Agua Blanca and Juan Manuel de Agua Negra, the lagoons La Belleza, La Negra, Juan Manuel, La Estrella and other smaller one as it is shown in the Map of the Figure 1.

Figure 1. Location of the Epicenters

Substantially it corresponds to a muddy ecosystem, of swamp forests and swamps besides, also a lacustrine estuary delta system in the area of the outlet of the rivers in the Lake of Maracaibo. This great esplanade shares the same geologic history that characterizes to the south of the Lake of Maracaibo, forming a depression between the mountain ranges of the Perijá and The Venezuelan Andes. The lagoons and flooded swamps exhale methane continually for decomposition of the detritus and humus, being the depth of the waters variable between the 2 and 4 meters, with warm temperatures between the 29 and 30º measures after the decline in the near observation points to the epicenters.

Figure 2. Characteristic aspect of the marshes.

2.1 Meteorological Conditions.

The mean annual temperature is of 28º C, being the maxim of 30º -36º C in the population of Los Encontrados to the 15 HLV, and the minimum one between the 23º and 25 ºC in the same place to the 5 HLV. The winds of the region present two circulations qualitatively different. Below the bench mark of 1500 m over the sea level, it presents a process of mandatory slip due to the mountains of the mountain ranges of the Perijá and of The Andes and it bears to the formation of convective clouds and of great vertical development between the 500 and 1500 m of height, during all the year, mainly to the foot of mount. To more height, on the 3000 m over the sea level, the direction of the winds and its mean speed is the characteristic for the rest of Venezuela [11].

Figure 3. General aspects of the Catatumbo River, near to the epicenters, notice the permanent cloudy and the muddy ecosystem.

It should be observed that the area of local convergence of winds, attributed by some authors [5] as causal agent of the phenomenon in study, it is presented very to the south of the Catatumbo river in fact and of the area that we are considering; such convergence is very near to the geographical axis of the towns of La Fría and El Vigía

The isoyetics maps don't evidence local maximums of pluvious in the region defined in the figure 1 and rather they evidence that the global climatic characteristics of the marshes are common to all the Lake of Maracaibo. The mean precipitation in summer is between 200 mm and 400 mm for the region in consideration, and of 800mm or more for the areas of convergence of winds in the foot of mount of the mountain ranges of The Andes and of the Perijá; similarly during the winter the mean precipitation is among 1000-1200 mm in the considered region, in front of values 1600-2000 mm for the surrounding areas [9].

2.2 Epicenters.

Three expeditions were made to the interior of the Park "Ciénagas de Juan Manuel" with the purpose of characterizing the "Lightning of the Catatumbo", beginning with the geographical location of the epicenter or of the epicenters. These expeditions were carried out with the collaboration of the National Institute of Parks (Ministry of the Atmosphere and Natural Resources, Venezuela) and the University of the Zulia (Venezuela), and they were reported firstly in the year 2000 by Falcon and collaborators [9] [11].

During the first expedition (10 at the 13-12-1998) it settled observation points in the town of "Los Encontrados", beside the Catatumbo river (09º 03,89' N 72º 14,14' W 440 m over the sea level) and in the delta of this river to the south of the Lake of Maracaibo, in the primitive lake dwelling of "Punta Chamita" (09º 05,77' N 71º 42,88' W 196 m over the sea level) the embraced area was also explored between both points along the course of the river. The results [9] evidenced that the phenomenon is presented in two regions very well located to the west of the Catatumbo, to the interior of the marshes, but particularly among the Lagoons La Estrella and La Bella, adjacent with the Bravo river. From the observation points the was visualized "Lightning of the Catatumbo" as gleams cloud-cloud and the phosphorescent splendor (lightning) in regions of the sky well located and persistently during all the night, although, for moments of until one hour it was stopped to observe due to clouds interposed between the observation place and the epicenters distant several dozens of kilometers to the interior of the marshes. It should stand out that other sporadic discharges were also observed with rays cloud-earth in other addresses of the sky but that they didn't present the light magnitude, persistence and almost periodicity of the discharges whose epicenters seem to be toward the region of the internal lagoons of the swamps of the national park "Ciénagas de Juan Manuel."

The second expedition that allowed locating the region of occurrence of the phenomenon was made among the days 20 at the 23 of July 1999 in the same interior of the swamps [10]. It settled observation places in: the town of "Los Encontrados" (9° 3' 5'' N 72º 14' 09'' W 14 m over the sea level), La Laguna Negra (09º 14' 13'' N 72º 06' 33'' W 36 m over the sea level) and the banks of the Bravo river (09º 14' 15'' N 72º 06' 31'' W 41 m over the sea level).

In the third expedition carried out in the summer of the 2000 the journeys riverside and lacustrine intermissions of the bases stations referred and the head of the Catatumbo River were explored. The results [10] corroborated the observations of the previous expeditions, in the sense of the existence of areas of epicenters in the proximities of the lagoons, to the interior of the marshes of the adjacent mentioned National Park with the Bravo River, instead of located points of occurrence of the phenomenon. As well as the persistence of at least two regions of the sky, very differed by their angular separation of up to 66º of azimuth, where the discharges take place. The map of the figure #1 sample the possible epicenters and their extension based on the observations carried out in the expeditions.

2.3 Characteristic of the electric discharges.

The photographic images (see imagines 4 and 5) evidence the characteristic discharges cloud-cloud of the phenomenon, and their relative confinement in a certain region of the sky. Particularly without the presence of extensive cloudy formations for the entirety of the visible horizon, like would fit of waiting in a typical storm. Notice that the rays of the atmospheric phenomenon are not cloud-earth neither earth-cloud, evidences that it seems to discard the presence of geothermal, geomagnetic or radioactive sources in the superficial substratum of the region. The electric discharges of the cloudy formation seem to come from only the deep interior of the cloud and not over its periphery or areas limit of the cloud.

Figure 4. General aspect of the lightning. The aspect should be noticed of "hair of the cloudy formation toward the right of the picture. The original colors are of an orange-reddish one in the brilliant part of the image

Figure 5.Discharge cloud-cloud observed with telescope to the interior of the cloud.

The picture #5 sample the descending rays between the two cloudy layers. The pressure values and temperature to the interior of these clouds, it can be considered starting from a lineal model for the troposphere [9] [10]. To 2,5 km high, bottom side of the cloud, the pressure reaches 0,75 atmospheres and the temperature is of the order of the 6°C. In the roof of the cloud the pressure decrease to 0,48 atmospheres and the temperature descends at -33°C.

On the other hand the characteristic electric activity among cloud-cloud bears to think that the epicenters move lightly, as the clouds are pushed by the local winds. The great vertical development of these cloudy groupings, doesn't allow rapids or big displacements regarding the epicenters.

Measures with the electrometer, at superficial level in the observation point to the banks of the Bravo river, give bill of the existence of atmospheric electric loads, depositing on the electrometer 0,015 micro coulombs in the lapse of 15 minutes that is equal to the increment of the difference of electric potential in the electrometer to reason of 0,33 volts per second.

On the frequency and other characteristics of the gleams (rays and lightnings) it should be pointed out that was not a characteristic frequency. It is evidenced that the discharges happen between 16 and 40 per minute, and after the observation of the rays to the interior of the clouds, a splendor is generated (lightning) phosphorescent in the environment, increased in magnitude by the reflection on the lacustrine mirrors of the flooded muddy area of calm waters (it Figures 3). All the discharges are deaf, and they are more frequent between the superior internal area and the inferior internal area of the own cloud. The color of the gleams (lightning) is orange-reddish and of very similar aspect to the one appreciated in the figures 4 and 5 like brilliant parts, the discharges (rays) evidence the characteristic electric blue color corresponding to the dielectric rupture of the air.

The electromagnetic spectrum of the discharge shows the typical emission of the line Hα of the Hydrogen, very weak to be photographed with the portable equipment transported on the boats of fishermen; only vehicles to move in the swamps.

2.4 Visibility of the phenomenon

The hours of visibility of the phenomenon are variable, between the 19 and the 04 HLV, and they seem to depend on the observation point. At relatively near distances to the epicenters, inside the marshes, the phenomenon begins to be observed with the disappearance of the zodiacal light, soon after of the decline. From more distant regions as the town of "Los Encontrados" it is at first sight observable when the sky is cleared in direction to the visual from this point and the regions of the lagoons, mainly in previous hours to the dawn (from the 01 hours HLV), or before using telescopes. As the observer moves away from the epicenters, the relative height of the "Lightning of the Catatumbo" regarding the horizon it diminishes, hindering its observation.

Similarly, from regions of high and distant observation, the visibility is increased. To be discharges to the internal of clouds cumulusnimbus and stratumcumulus, an observer placed exactly in the epicenters, under

the layers of clouds where they take place the discharges, doesn't appreciate the phenomenon.

The phenomenon begins to show soon after of the decline, even with the zenithal or twilight light; but it is not visible by nude sight; however if it is photographically detectable like it is illustrated in the figure 6, notice the absence of storm clouds.

Figure 6 The Lightning from the Bravo River, instants after the decline, when not yet it is visible at first sight.

The data obtained and the described phenomenology allows proposing an explanatory model of the origin of the phenomenon and its physical mechanism of occurrence that we will describe next.

3. Microphysics Model.

The extension of the swamps, permanently flooded, makes think that the gas methane should play an important list in the microphysics processes that take place in the clouds of the region. As the methane molecule (CH_4) is lighter than the air, the hydrostatic push transports it toward the highest layers of clouds, even above the clouds of vapor of water.

In recent years the importance of the methane has been pointed out in the study of phenomena oceanographic, especially the called methane ice that flames spontaneously and it is characteristic of the polar regions and of the abyssal zone of the oceans, where the pressure and temperature are very low [13].

Figure 7. Ice of incandescent Methane. The cu coloration of the flame and the spectrum is identical to that of the Lightning of the Catatumbo.

The relative intensity of emission or absorption of electromagnetic radiation of certain wavelength, in particular of the light, it is determined by the traverse section of absorption. The values of this magnitude in the Hydrogen line Lyman α, detected in the measures of the electromagnetic spectrum of the lightning of the Catatumbo, are very high for the methane, what allows supposing that the gleams (lightning) are produced by the presence of this gas in the high clouds of the atmosphere of the region. Indeed for the methane the traverse section of absorption overcomes the vapor of water and it is much bigger that the values corresponding to the nitrogen and the gassy oxygen [14].

The fluorescence observed as lightning, after the generation of rays to the internal of the high clouds, can be due to the existence of "unstable" states of the methane molecule and of the radical methyl, in which stay a very brief time, for them emit light (Metastables States). The lifetime of the Metastables States is comparable to the duration of the diffuse discharge (lightning); typically in the range of the nanoseconds to the milliseconds [9].

Known the pressure and the temperature to the internal of the clouds, based on a lineal atmospheric model and using the Equation of Saha (see [10] and reference in it), it is possible to estimate the grade of ionization of the methane. Of the carried out observations "in situ" it is considered the maximum height of the clouds where takes place the phenomenon, in 6,4 km ± 0,2 km, then the grade of ionization of the methane is from the order of 58% to this height 10.

On the other hand, the decrease of the atmospheric pressure allows the condensation of

the methane in crystals in the high parts of the clouds.

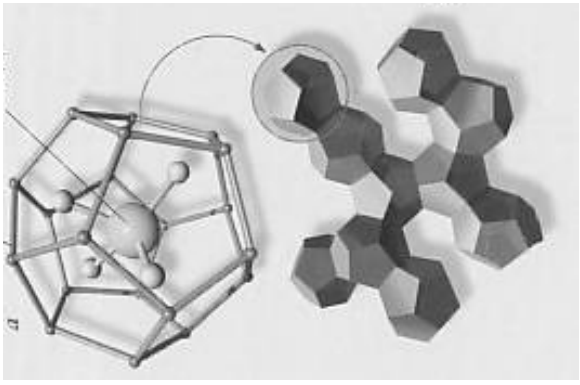

Figure 8. Symmetry of the Methane Crystals.

The peculiar symmetry of the molecule of the methane, denominated tetrahedral symmetry Td in the notation of Schoenflie, transforms them into pyroelectrics crystals; it is worth to say in crystals that polarize spontaneously [15], all time that the vector of electric displacement D is in the way:

That it conserves a non-null value, even in absence of electric fields (E=0). When condensing the methane, it would be formed crystals that polarize spontaneously due to the tetrahedral symmetry, causing a gradient of electric potential in the cells of the high layers of the cloud. When the electric potential of the cell of the cloud overcomes the potential of dielectric rupture of the air, the discharge is generated, visible in form of rays to the internal of the same one.

The gas methane inside the cloud is in hydrodynamic balance with its surroundings, but not in thermal balance, reason why the temperature of the gas will be bigger than the temperature of the surrounding atmosphere. The temperature of the gas is of the order of 448 ºC, corresponding to the pressure in the benchmark of maximum height 6,4 km. These values allow estimating that the mean quadratic speed of the payees of loads is of the order of 890 km/s. In consequence the loads move for the air to a superior speed to the speed of the sound (supersonically) like would fit of waiting for the atmospheric electric discharges (rays).

If the intensity of the electric field of the cloud is of at least the corresponding to the atmospheric electric field under normal conditions (100 Volts per meter), then the potential difference among the heights superior and inferior of the cloud is of the order 220 000 Volts. Supposing that the discharge happens among the heights maxim and minimum of the cloud (cloud-cloud ray) the current intensity is of the order 130 million amperes for a typical ray with diameter 1 square centimeter in the discharge canal and the liberated energy reaches the value of a million Joules.

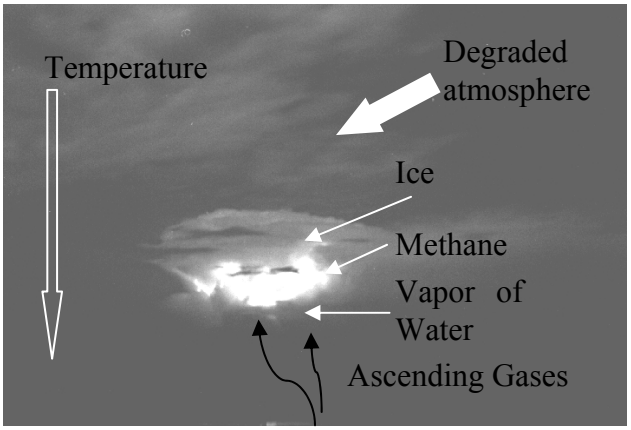

Figure 9: Microphysics Model of the Lightning of the Casaubon.

The ray would cause the ionization of the material in the discharge canal, and the liberated energy will increase the temperature inside this canal to 35.000 Kelvin. For these values the discharge (ray) can be modeled as an ionized gas or electronic plasma. In electronic plasma the relaxation time is of the order of 0,9 microseconds (Falcon, et al 2000), lapse after which the plasma cools down and the discharge stops. It would imply that the intermittence of the rays is inherent at the “cooling” time (relaxation time) of the temperature of the plasma formed in the canal of discharge of the ray, details of such a pattern can be seem in the references [9 - 12].

4 Conclusions

According to the proposed pattern the methane would be the causal agent to understand the phenomenon known as the "Lightning of the Catatumbo". The concentration of this gas in the breast of the convective clouds on the region would cause the separation of electric loads inside the cells of the clouds, facilitating the discharges (rays) as well as the phosphorescence (lightning) observed. It is in agreement with the level of current knowledge on electric discharges in ionized gases and with the physical-chemical properties of the methane, like it was shown in the precedent section. Also the concentrations of Methane in the terrestrial atmosphere vary among percentages of 1.5 millionths to 10 km of altitude, to 1.1 to 20 km of altitude [15] under normal conditions.

The fact that the discharges happen to the interior of the clouds (rays cloud-cloud) it seems to discard the existence of ionize agents and geomagnetic in the substratum, also it could explain the un detection of the phenomenon from meteorological satellites as the "Optical transient Detector", designed to measure the atmospheric electric activity and the storms.

During the day the phenomenon would not take place because the solar irradiance photo dissociate a methane continually, impeding the electric auto polarization of the cloud. After the decline or during a total eclipse, as it happened in this region the 26-02-98, the electric activity of it, is manifested of the "Lightning of the Catatumbo" even before the temperature changes considerably (Figure 6). During the winter or after precipitations of great magnitude on the region, the visibility of the phenomenon diminishes and even disappears completely. It would be explained because the intense and/or lingering precipitations drag the methane toward the surface and it diminishes the relative concentration of the gas. Similarly, during the dry station (summer) the evaporation and the stocking temperature are increased, allowing the volatility of the gas and their quick ascent to the high layers of the clouds where they would be formed crystals auto polarized electrically.

The winds don't dissipate the relative accumulation of the methane because this is caught to the interior of the clouds. This process of accumulation can be favored by the existence of a local center of low pressure located between the Bravo and Catatumbo rivers that carry the closed circulation of the winds for inferior benchmarks to the three thousand meters.

The relative displacement of the epicenters is explained by the mobility of the clouds, when the convective clouds increase its vertical development, they are pushed toward the lake of Maracaibo and the rich superior layer in methane its vanishes. The dissipation takes place for action from the existent trade winds to bigger bench marks to the three thousand meters and, mainly, for the liquation and coalescence of the methane drops to the interior of the cloud.

The marshes increase the stateliness of the lightning for the speculate reflection on the lagoons of calm waters and in visual direction to them. The inaudible character of the discharges is explained because the rays happen to great height, among two thousand and three thousand meters, and the sound of the shock wave generated by the rupture of the discharge canal is muffled inside the cloud.

The inferior layer of the cloud enriched with superficial electric loads, for the electric induction and for the liquation of the methane, causes the sporadic ray's cloud-earth exactly when the clouds are forced to move on the riversides of the lake, such as they are observed possibly without the characteristic fluorescent splendor of the "lightning of the Catatumbo."

Figure 10 Sporadic discharges cloud-cloud. Notice the absence of clouds of storms and the trajectory of the discharge.

It is to explain the anomalous concentration of the methane in the low part of the local atmosphere. A commendable reason is the enlarges area of swamps (near 226 000 hectares) located in a tropical climate with closed circulation of winds in an area of low pressure.

Another possibility is the presumption of the existence of kerogeno III in the substratum, typical of deposits of hydrocarbons and of high concentrations of methane. The substratum of the lake of Maracaibo is rich in oil deposits and shares with the riverside marshes the same geologic history. This way the methane accumulation in the atmosphere could see it turns favored by the escape of this gas through fissures in the rocky mantel to the interior of the marshes (lagoons). It could explain the observation reported by Centeno [1]. About the "mysterious disappearance of the lightning" in some cases, or the sudden increment of the activity of the lightning in other, immediately after the occurrence of intense earthquakes of the region.

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