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Atmospheric Anomalies in Summer 1908: Water in the Atmosphere

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Abstract—A gigantic noctilucent cloud field was formed and different solar halos were observed after the Tunguska catastrophe. To explain these anomalous phenomena, it is necessary to assume that a large quantity of water was carried into the atmosphere, which indicates that the Tunguska cosmic body was of a comet origin. According to rough estimates, the quantity of water that is released into the atmosphere as a result of a cosmic body's destruction is more than 10^{10} kg. The observation of a flying object in an area with a radius of ≥700 km makes it possible to state that the Tunguska cosmic body looked like a luminous coma with a diameter not smaller than ≥10 km and became visible at heights of >500 km. The assumption that the Tunguska cosmic body started disintegrating at a height of ~1000 km explains the formation of an area where its mater diffused and formed a luminous area above Europe.

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1. INTRODUCTION

The effects related to the action of the Tunguska cosmic body (TCB) on the Earth's atmosphere can be conditionally divided into several groups: First, a field of luminous clouds extending over more than 10 mln km^2 was formed after the Tunguska catastrophe. The region of "white nights" extended from Eniseisk and Krasnoyarsk, which is located slightly west of the crash site of the TCB, to England, and its southern boundary reached the Black Sea and Tashkent (Whipple, 1930; Zotkin, 1961; Fesenkov, 1968). Second, an anomalous state of the dayside atmosphere in England and Norway was observed ~12 h after the TCB explosion. Inhabitants of Oxford, Oslo, Yekaterinburg, and other cities in Europe and Asia mentioned that different solar halos in the form of rings and columns appeared and false suns were observed. In the majority of cases, light nights over Russia and Europe appeared twice; at the same time, the anomalous state of the dayside atmosphere lasted for several months in some areas. In Grossfolk near Hamburg, false suns and extremely rare configurations were observed in July and August 1908. It is important to note that white nights were only observed in Europe and partially in Asia, whereas halos and crouns around the Sun were even observed at several points in the United States (Utah and Washington states). Specifically, in Washington, solar halos were observed on July 1 and 2 (Vasil'ev et al., 1965). Third, the transparency of the Earth's atmosphere decreased in Europe and America. A short-term, but rather considerable, decrease in the transparency of the atmosphere, apparently independent of the level of cloudiness, was observed on July 4–6 in Paris (Vasil'ev et al., 1965). At Mount Wilson in California, it was registered that transparency had very pronouncedly decreased since the second half of July 1908 (approximately two weeks after the Tunguska catastrophe) (Turco et al., 1982).

The observed phenomena are explained in several ways. The origination of white nights after the Tunguska catastrophe is most often related to the formation of a gigantic noctilucent cloud field (Shönrock, 1908; Vasil'ev et al., 1965; Romejko, 1991). Numerous eyewitnesses observed the structure of these clouds (Whipple, 1930; Rudnev, 1909; Polkanov, 1946). However, it is still insufficiently clear how the TCB affected the formation of noctilucent clouds. The appearance of anomalies in summer 1908 was related to the penetration of comet tail dust or a dust cloud of rapidly precipitating substance into the atmosphere (Fesenkov, 1961; Bronshten, 1991). A decrease in the transparency of the atmosphere is undoubtedly related to the dust content of the atmosphere. However, the global propagation of white nights can in no way be related to dust. Shönrock (1908) noted that the time of dust precipitation from the upper atmosphere is much larger than the period during which luminous clouds were observed. After the explosion of the Krakatoa volcano, dust remained in the atmosphere during several months rather than two days. It was assumed that the luminosity of the atmosphere was related to the recombination of ions. However, neither the emission of molecules and atoms, excited by the passage of the TCB, nor auroras could have caused light nights, since astronomers could not find any emission lines in the nightglow (Shönrock, 1908; Zotkin, 1961).

2. COMET NATURE OF THE TCB

Halos are atmospheric optical phenomena related to refraction and reflection of the Sun's light in ice crystals suspended or falling in the air. Noctilucent clouds observed at heights of 74–92 km are mainly composed of ice crystals formed on condensation nuclei in the vicinity of the mesopause (~82 km). Consequently, it is necessary to add water to the atmosphere.

Most theories that consider the atmospheric anomalies in summer 1908 proceed from the comet nature of the TCB (Astapovich, 1958; Fesenkov, 1961; Zotkin, 1961; Turco et al., 1982; Bronshten, 1991; Romejko, 2008), since the meteorite nature of the TCB does not make it possible to explain the change in the water balance of the atmosphere. Only one researcher tried to explain the anomalies in summer 1908 not using the comet hypothesis. Romejko (1991) related the atmospheric anomalies to the gravity waves caused by the explosion of the TCB. We should note that gravity waves could affect the origination of noctilucent clouds; however, in 1908, the noctilucent cloud field was thicker than barely perceptible sheets that are usually observed at mesopause altitudes. Numerous eyewitnesses observed an unusually light glow, which mostly continued up to sunrise and covered the entire area of Europe (Shönrock, 1908; Rudnev, 1909). Before and after summer 1908, such a large-scale occurrence of noctilucent clouds was not registered, although explosive gravity waves repeatedly affected the temperature regime of the mesopause.

It was doubtful that the atmospheric anomalies were caused by the Tunguska catastrophe. The main argument consisted in that individual light twilights had been observed before the Tunguska catastrophe. However, as was mentioned above, the intensity of the precatastrophe atmospheric effects was much lower than that of the effect observed after the catastrophe. To explain these facts, it is natural to assume that two effects superposed in summer 1908: white nights caused by the Tunguska catastrophe and the annual occurrence of noctilucent clouds in the summer.

Thus, according to the atmospheric effects observed in summer 1908, the TCB could only be of a comet nature.

3. ENTRY OF THE TCB INTO THE ATMOSPHERE

Only isolated observations of the comet, a fragment of which could be the TCB, are available (Romejko, 2008); therefore, it is reasonable to assume that the TCB was not an active comet before the interaction with the Earth's atmosphere. However, according to the observations of numerous eyewitnesses, the TCB was observed from a distance of $R_{obs} \geq 700$ km in the Earth's atmosphere on a shiny day (Astapovich, 1951). This is another argument in favor of the comet nature of the TCB. It is known that the region of meteorite luminosity is comparable with that body's dimensions, since luminosity is related to the shock formation on a flying object's frontal face. An object of the size of $D_{obj} \sim 100$–200 m (the supposed size of the TCB) had to be observed as a point from a distance of R_{obs}, which contradicts the eyewitnesses' testimonies. Moreover, meteorites start shining at heights of $H_{met} \sim 100$ km. From a distance of 700 km, a body at a height of H_{met} should be located near the horizon, which also contradicts the observations of the witnesses. Consequently, the observed object could only be a comet. In this case, if a comet's head dimension is D_{obj}, the coma size mainly depends on the ambient air density. The air density decreases and, consequently, the coma size around an object increases with an increasing comet height.

3.1. Observed Object's Dimensions

An observer from the Murskii threshold noted that the flying body was "much larger than the Sun" (Krinov, 1949), whereas eyewitnesses from Kezhma and Kova reported that the body was "three times as large as the Sun," "much larger than the Sun" (Krinov, 1949), and "much larger than the Moon" (Naumenko, 1941).

The distance L from the observers in Kezhma to the projection of the object flight trajectory on the Earth's surface is ~560 km. This distance is even larger for the Kova and Murskii thresholds. The TCB trajectory will not be discussed in this work. However, it should be noted that we cannot use a smaller L value in calculations, because the trajectory is attached to a point above which the TCB crossed river Lena. The TCB trajectory crossed Lena near Mironovo (Epiktetova, 1976, 2008) and Petropavlovsk, where a spark from the cosmic object split a pine tree on a mountain according to the observations of natives.

The visible angular diameter of the Sun and the Moon is $\theta = 1/2°$. If the dimensions of the object were equal to the visible diameter of the Sun and the Moon for the observers in Kezhma, its diameter would be $D = L^*\sin\theta \sim 5.0$ km, where L^* is the distance from an observer to an object (assume that $L^* \sim 600$ km). The upper boundary of the TCB visible dimension is assumed to be $D_{up} = 3D \sim 15.0$ km. However, when observers state that the body was "three times as large as the Sun," they possibly mean that the body's luminous surface (S_m) was three times as large as the visible luminous surface of the Sun (S):

$$S_m = 3S = 3\pi\frac{D^2}{4}.$$

From this, it follows that the lower limit of the visible dimension of the TCB is $D_{un} \sim 8.5$ km.

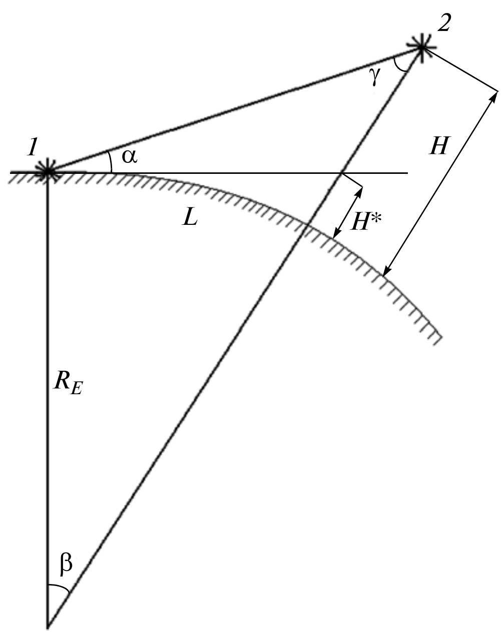

Fig. 1. Schematic location of an observer (*1*) and an object (*2*).

3.2. Object Occurrence Height

In addition to the fact that the TCB had a large visible dimension, it should be noted that this body occurred at altitudes much higher than the meteor firing altitude. Observers from Kezhma (Naumenko, 1941) and Kamenskoe, which is located on river Yenisei at a distance of 600 km west of the cosmic body fall site (Krinov, 1949), noted that an object passed near the Sun. The height of an object above the Earth's surface can be determined in the following way. We assume that L is the distance from an observer to the point below that object along the Earth's surface, α is the angle between the horizon and the direction to the object, β is the angle between the directions toward the observer and the object from the Earth's center, γ is the object angle (Fig. 1), and $R_E \sim 6370$ km is the Earth's radius. In such a case, the object's height above the Earth's surface (H) will be written in the following form, using the sine law

$$H = R_E\left(\frac{\cos\alpha}{\sin\gamma} - 1\right),$$

where $\beta = \dfrac{L}{2\pi R_E}360°$ and $\gamma = 90° - \alpha - \beta$.

Part of this height behind the horizon (H^*) is defined as

$$H^* = R_E\left(\frac{1}{\cos\beta} - 1\right).$$

According to Naumenko (1941), the TCB trace was mostly projected on the solar disk. During the TCB flight, the Sun was located at an angle of $\alpha \sim 27°$ for an observer. For Kezhma, $L \sim 560$ km; consequently, the TCB was observed at $H \sim 330$ km. For Kamenskoe (on Yenisei), $L \sim 1000$ km; consequently, the TCB would have been at a height of $H > 680$ km if it were projected on the solar disk. The TCB visibility height could be lower, since (as was noted) an object "detached from the Sun"; however, it should be taken into account that $H^* \sim 90$ km for Kamenskoe. The error will be insignificant if we assume that the body's observation height from Kamenskoe was 500–700 km above the Earth's surface. Based on eyewitnesses' evidence, Epiktetova (2008) determined that the TCB occurrence height was substantially higher (>1000 km).

Thus, the TCB became visible at altitudes close to 1000 km, which is much higher than the altitudes where meteorites appear. The extent of the luminosity zone around the cosmic object at an altitude of ~300 km was ~10 km, which was by two orders of magnitude larger than the assumed diameter of the cosmic body itself.

4. INTERACTION BETWEEN THE TCB AND THE ATMOSPHERE

It is assumed that a comet moved toward the Earth from the Sun (this explains why it had not been observed before the catastrophe). In this case, its tail (accelerated by the solar wind and solar radiation pressure) could have reached the Earth's orbit before the body itself. However, it is still unclear how the dust and gas in a comet's tail would interact with the Earth's magnetosphere. Ionized molecules and particles should be deflected by the geomagnetic field. Water ions cannot be accelerated so that they could penetrate into the Earth's magnetosphere. Moreover, they will disintegrate when interacting with the constituents of the Earth's atmosphere. Uncharged water molecules can diffuse through the magnetosphere toward the Earth, but the duration of this process is much longer than the lifespan of water molecules decayed by solar radiation and the period during which anomalous effects were observed in summer 1908. Only rather large bodies can cross the magnetosphere.

As was previously indicated, the TCB became visible and started discharging some matter at altitudes of $H_{dis} \sim 1000$ km. It is assumed that the cosmic body's disintegration was explosive at these altitudes (Epiktetova, 2008). This follows from the evidence of witnesses from the Aleksandrovka village and Altai krai, who observed the TCB from the gorge bottom: "*At seven o'clock in the morning, sunrise had already taken place, but the Sun had not yet appeared from behind the Glyaden mount. Then, a light ball suddenly appeared in the sky, and its dimension and brightness rapidly increased ... When this ball appeared, the entire locality unnaturally illuminated, and this illumination was oscillating and looked like wave-like flashes ... The unnatural oscillating light was terrible ...*" (Epiktetova, 2008).

The increase in the object's dimensions, as well as the change in its brightness, can be explained by explosive matter discharges. Sparks that escaped from the body and burned with cracking noise, according to numerous witnesses (Epiktetova, 1976), as well as sounds, indicate that the interaction between the TCB matter and the atmosphere was explosive during the entire flight ("... flew at a very low height ... and cracked very frequently") (Suvorov, 1976).

It is assumed that comets explode in the Earth's atmosphere at altitudes of ~1700 km (Frank et al., 1986). This hypothesis was proposed in order to explain the observed short-term "atmospheric holes" in the UV range. The Dynamics Explorer 1 satellite registered a 5–20% decrease in the intensity of natural dayglow in the UV range at the atomic oxygen wavelength (103.4 nm). This UV radiation weakening lasts several minutes. It is assumed that a small comet with a mass of $M_{com} \sim 10^5$ kg changes into a particle swarm and flies in an expanding cone. Water vapors, which absorb UV radiation, are most probably released when this comet breaks down (Frank et al., 1986). The telescopic observations performed at the Arizona University do not contradict this assumption (Yeates, 1989).

Only this hypothesis concerning explosive interactions between comets and the atmosphere makes it possible to explain a number of data, which were experimentally found when space was studied. First, according to balloon and rocket twilight atmospheric sounding, the dust content of the atmosphere is considerable at altitudes higher than 100 km and rapidly increases with increasing altitude. The particles of an exploded comet should be decelerated precisely at these altitudes. Second, short-term (shorter than 40 min) and very considerable increases in the dust particle impact registration frequency were registered on the Prospero and GEOS-2 satellites. It is assumed that the satellites crossed dust jets caused by explosions of the nuclei of small comets at those instants. Third, one only fails to explain the quantity of water in the thermosphere, mesosphere, and upper stratosphere due to the diffusion of water vapors and methane (with subsequent decomposition) from the near-surface atmosphere. Water should inflow from space (Lebedinets, 1991).

It is customary to assume that the upper boundary of the atmosphere, as a gas shell of the Earth, reaches altitudes of 2000–3000 km. Comets entering into the atmosphere at the cosmic velocity are bombarded by ionized atoms and molecules, as a result of which their structures can be destroyed. The causes of beak down of small comets and the explosive matter discharge from the TCB surface at H_{dis} should be similar to the causes of an abrupt change in comets' brightness (flashes) observed when they approach the Sun, comet nuclei fragmentation, and interactions between comets and the Earth's radiation belt's particles; however, one should continue studying this problem.

5. MATTER DISPERSION TRAIL

Discharged matter (even with an organic component) can reach the Earth's surface, if it looоses its cosmic velocity as a result of an explosive discharge from the corresponding cosmic body's surface. Particles that retain the cosmic velocity start burning or melting at H_{met} altitudes. In this case, only the refractory components of discharged matter can reach the Earth's surface.

According to numerous eyewitnesses' evidence, obscuration took place on the day of the Tunguska catastrophe, "It was noisy. Night fell and was subsequently replaced by day. When it was noisy, it was daytime, which was replaced by night and day again" (Epiktetova, 2008). In the presented quotation, noise means sound effects that accompanied the TCB destruction (in more detail, see (Gladysheva, 2009)). The obscuration was mostly similar to twilight and lasted $h_{pot} \sim 1$ h. This obscuration was observed several hours after the catastrophe and coincided with the audibility of the sound effects and even with the body flight instant in several cases. For the majority of eyewitnesses, the TCB flew between them and the Sun; therefore, the discharged matter, which moved toward the Earth in the form of a cloud, could cause the effect of temporal obscuration.

A considerable part of a cosmic body's discharged matter will evidently continue moving along the trajectory of this body. In the case when a cosmic body's matter can reach the Earth's surface, the precipitation area of this matter can be determined based on, e.g., the effect of this matter on vegetation. Several facts indicate that the biomass gain is related to the matter of the TCB. First, it was registered that trees grew much more intensely at the epicenter of the Tunguska catastrophe and along the TCB trajectory (Nekrasov and Emel'yanov, 1964; Dragavtsev et al., 1975; Vasil'ev and Batishcheva, 1976); this indicates that a certain new factor stimulated tree growth when the TCB matter was added to soil. Second, a series of experiments was devoted to the effect of fertilizers on growth of crops, the composition of which was similar to that of the ash from the peat layers sampled at the TCB explosion epicenter and corresponding to the time of the Tunguska catastrophe (Golenetskii et al., 1977). As a result, it was detected that the crop capacity of meadow grass, potato, and flax was substantially increased (Zhuravlev and Zigel', 1998). Thus, it was proved that the TCB matter promoted an increased biomass gain.

Kasatkina and Shumilov (2007) determined the region with an increased annual tree growth related to the Tunguska catastrophe (Fig. 2). This region (about 2 mln km^2) is located north of the explosion epicenter and is slightly shifted westward. It extends up to the Arctic Ocean. If the cosmic body was mostly moving northward when the matter was discharged at altitudes from H_{dis} to H_{met}, we can superpose the northern seg-

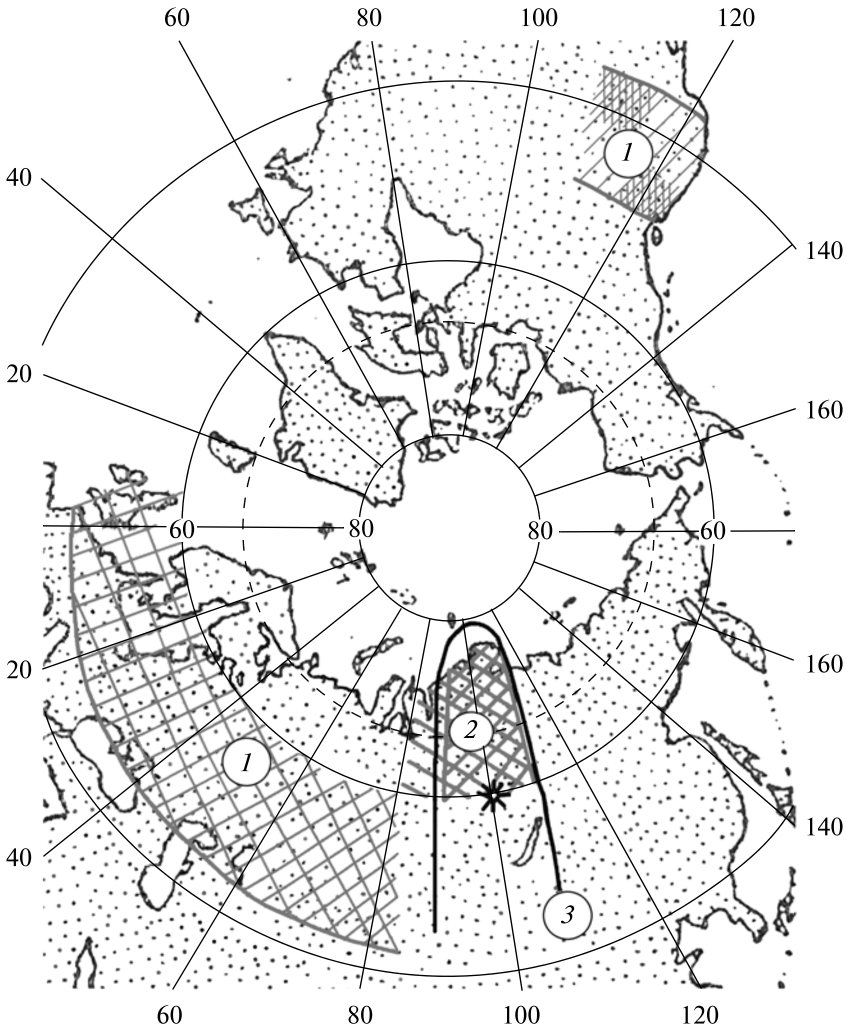

Fig. 2. The Earth's Northern Hemisphere: (*1*) the regions where optical anomalies were observed in summer 1908; (*2*) the region where trees intensely grew after the Tunguska catastrophe (Kasatkina and Shumilov, 2007); and (*3*) the northern segment of the TCB matter dispersion ellipse. The explosion epicenter (~61° N, ~102° E) is marked by an asterisk.

ment of the TCB matter dispersion ellipse (Fig. 2) with the zone of accelerated tree growth, taking particle dispersion into account.

6. WATER IN THE ATMOSPHERE

Since the TCB disintegrated during the flight, a substantial part of its matter was in the Earth's atmosphere. When the TCB was destroyed above the epicenter, the main mass of the matter of the body's remaining part was also carried into the atmosphere. This is confirmed by eyewitnesses, who observed that first a flame appeared above the area where the body disappeared behind the horizon and a cloud was subsequently formed. According to S. Ovchinnikov, "in Kirensk, the explosive column was similar to a benzene or magnesium flash, after which a cloud originated as is usually observed during strong explosions or volcanic eruptions ... The explosion was instantaneous, but dark explosion products were observed in the air for several hours in the form of a cloud, which subsequently became gray or ash gray and more transparent" (Astapovich, 1951). The appearance of a cloud was detected by every second observer of the 30 observers, whose accounts were published in the catalogs of Voznesenskii (1925) and Konenkin (1967). Since a cloud, including the remainders of the TCB, was observed from a distance of ~500 km, the calculated cloud height is ≥80 km. The mechanism, by which explosion products were carried to such a height, is proposed in (Gladysheva, 2009).

To estimate the quantity of the water introduced into the atmosphere, it is necessary to perform additional studies based on the characteristics of the evening and nighttime luminosity and other atmospheric effects of summer 1908. The quantity of the water that appeared in the atmosphere can only roughly be estimated based on indirect data. According to Fesenkov (1949), who based his estimates on the haziness of the atmosphere as a result of the TCB ingression, the mass of the dust that appeared in the atmosphere was $n \times 10^9$ kg. Based on the similarity of the TCB matter to carbonaceous chondrites, Golenetskii et al. (1981) estimated the ratio of volatile substances to mineral ones in the body. According to their assumption, the percentage of mineral particles in the initial TCB matter was not more than 0.1%; consequently, the initial mass of the TCB was $n \times 10^{12}$ kg, and the quantity of water in this mass was $\sim 10^{12}$ kg. Proceeding from the proportions of dust and water proposed in (Lebedinets, 1991), we can assume that the quantity of water in the TCB could have been 10^{10}–10^{12} kg. According to the body disintegration pattern proposed in (Gladysheva, 2010), the final body mass above the epicenter was $\sim 5 \times 10^9$ kg; consequently, the quantity of water released by the TCB into the atmosphere should have been not less than 10^{10} kg.

7. ATMOSPHERIC ANOMALIES

Daytime, twilight, and nighttime phenomena related to noctilucent clouds and light refraction by ice crystals were observed over Europe and partially over Asia in the region limited by Krasnoyarsk's latitude in the east and by the Tashkent–Odessa line up to the Bretan' Peninsular in the south (Fig. 2). According to Zotkin (1961), the western segment of the southern boundary is located further north than the eastern one. The northern boundary of the region with anomalous effects is indefinite, since it cannot be distinguished against the background of white nights and the nonsetting Sun.

The field of noctilucent clouds was formed as a result of crystallization of water vapors, which were released when the TCB was disintegrated and reached altitudes of 70–90 km. The time of observation of light nights depends on the ice crystal settlement rate at these altitudes. Descending under the action of gravity into the mesosphere, where temperature rises with decreasing altitude, the ice crystals had to lose water up to the complete disappearance. This explains the fact that white nights over Europe and Asia were only detected during two days.

It is not sufficiently clear at what altitudes halos appear. A halo appeared before light twilights and was observed during several months. Halos are usually observed in clouds at stratospheric altitudes (10–20 km); however, visible obstacles for the formation of halos by crystals of noctilucent clouds are absent. According to Cave (1908), a halo was formed by clouds that were located above usual cirrus clouds; therefore, it is natural to proceed from the fact that the appearance of solar halos is caused by noctilucent clouds.

In Europe, anomalous effects were observed at a distance of $S_{op} \sim 6000$ km $h_{op} \sim 12$ h after the Tunguska catastrophe. Consequently, the velocity of the matter westward motion (V_{fr}) from the TCB matter discharge trajectory can be estimated as $V_{fr} = S_{op}/h_{op} \sim 140$ m/s. Such a velocity is too high for atmospheric winds. According to Ivanov (1967), winds that can carry matter towards the west at an average velocity of ~50 m/s exist at altitudes higher than 100 km. Romejko (1991), in turn, stated that winds predominant in this season in the upper atmosphere had to carry matter eastward rather than westward. A faster eastward–westward current was observed by Wolf in Geidelberg on July 2, 1908; a cloud similar to smoke moved at a velocity of 1° per minute. Assuming that the velocity of the current was 60 km, Whipple (1930) found that the velocity of the cloud was ~100 m/s.

Taking into account the location of the Sun during the Tunguska catastrophe, we can assume that the shape of the eastern, southern, and western edges of the region with atmospheric anomalies depends on the transfer of the matter under the action of solar radiation. During the Tunguska catastrophe, the Sun was east of southeast. Under the action of solar radiation, small fragments within the TCB matter dispersion ellipse first had to be carried almost westward and northward near noon until they were decelerated at H_{met} altitudes. The water that appeared in the atmosphere had to be released during the period when these fragments were displaced and decelerated.

We now estimate the particle displacement velocity under the action of solar radiation only. Acceleration in the dust tails of comets related to sunlight pressure is close to $a_{sol} \sim 6 \cdot 10^{-3}$ m s^{-2} by an order of magnitude (Andrienko and Vashchenko, 1981). Assume that a particle has a starting western velocity component of $V_{st} = 0$ km/s. In such a case, the particle will move at an average velocity of $V_m \sim 120$ m/s, when it only propagates in the absence of collisions during h_{op} with acceleration a_{sol}. This value is comparable with the required transfer rate. However, particles are not only affected by sunlight pressure, but also gravitation and, probably, forces related to the geomagnetic field. In addition, at $\leq H_{met}$ altitudes, particles will not be able to move in a collisionless mode.

Matter transfer can be accelerated as follows. According to present-day concepts, comets represent a conglomerate of balls (nodules) of different sizes. This was probably true for the TCB, since eyewitnesses observed an object that flew accompanied by several much smaller fragments. These eyewitnesses compared the TCB with a house and its fragments with barrels, and the latter flew (burning and cracking) over a distance of about three cosmic body diameters (Epiktetova, 1976). We can assume that explosions at altitudes from H_{dis} to H_{met} could also result in the formation of sufficiently large fragments ejected from a body with nonzero western velocity components, especially as the TCB most frequently moved northwestward according to the evidence of eyewitnesses.

These large fragments of the observed body, which were completely disintegrated over Europe, could be responsible for the local anomalies that happened ~12 h after the ingression of the TCB. In addition, similar fragments could also deliver water to America, which would explain the anomalies observed in this region (Fig. 2). The main mass of the water from the TCB matter dispersion ellipse was most probably transferred during a longer period; however, this problem should be additionally studied.

Judging by the fact that white nights were on average observed during about two days, we can conclude that the main mass of the water carried by the TCB into the Earth's atmosphere crossed the mesopause region during this period. However, solar halos were also observed during much longer light twilight periods at certain localities. This could be related to vertical vapor diffusion in the atmosphere, as a result of which water enters atmospheric regions with anomalously low temperatures at altitudes of the mesopause and stratosphere.

8. CONCLUSIONS

The anomalous phenomena of summer 1908 can only be explained proceeding from the TCB comet nature, since noctilucent clouds and halos cannot be formed without a change in the water balance of the atmosphere. Assuming that comets start interacting with the Earth's atmosphere at altitudes of 2000–3000 km, as a result of which they are fragmented and start discharging matter at altitudes of ~1000 km, we can explain why a considerable amount of water vapors ($\geq 10^{10}$ kg) and dust ($n \times 10^9$ kg) enter the Earth's atmosphere. A giant field of noctilucent clouds was formed after the crystallization of water vapors on dust particles at altitudes of 70–100 km. The field density was much higher than the usual value, since a solar halo was observed through this field during daytime, and stars were almost unobservable at night. The noctilucent cloud field's shape over Europe and partially Asia depends on the dispersion cone of the mater that was discharged at altitudes of $\geqslant 100$ km, owing to the displacement of small TCB fragments under the action of solar radiation and atmospheric wind pressure. The origination of a matter dispersion plume north of the Tunguska catastrophe area and numerous observations of the obscuration that followed the passage of the body can also be explained by the discharge of matter at altitudes much higher than the meteor occurrence altitude.

Proceeding from the assumption that swarms of small comets can exist in comet orbits (Lebedinets, 1991), we can explain the light nights that had been observed several days before the Tunguska catastrophe. Assuming that the TCB is a fragment of a disintegrated comet, we can assume that this body was surrounded by fragments of small comets. These comets disintegrate at an altitude higher than 1000 km and subsequently move as a swarm of particles. This swarm is decelerated at altitudes of 100–300 km, delivering water and dust to these altitudes. Small comets are almost invisible, and it is very difficult to detect them instrumentally. Only the largest bolides and meteors, including the TCB, are observed. The penetration of water and dust into the mesopause altitudes, as a result of which noctilucent clouds are formed, could be observed during light nights before the Tunguska catastrophe.

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