GEOPHYSICAL CIRCUMSTANCES OF THE 1908 TUNGUSKA EVENT IN SIBERIA, RUSSIA

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Abstract. On the morning of June 30, 1908 a remarkable natural phenomenon took place in the region to the north and north-west of Lake Baikal in Russia, which is now usually known as the Tunguska event. Despite the fact that a dozen explanations or more have been put forward to explain this event, its origin is still questionable.

In this work geophysical circumstances of the Tunguska event are investigated. The research reveals that the event took place during a strong upsurge of tectonic activity in the Tunguska event region, and there were some peculiarities in tectonic activity even on larger scales. Also the event occurred during a change from a long period of "good" weather to a "bad" one in the region. And there were also peculiarities in the atmosphere on larger scales at those times.

In the author's opinion, this suggests that the Tunguska event was of geophysical origin. On much smaller scales similar geophysical events occur rather often.

1. Introduction

The problem of the nature of the 1908 Tunguska event has already excited researchers over the course of many decades (Vasilyev, 1998). On the morning of June 30, 1908, the ground trembled north and northwest of Lake Baikal in Central Siberia, and underground jolts and reverberations struck panic into hearts of the local population.

Reports of a glowing body flying over came from various points of the territory. A forest fall with an area 2150 sq. km in the northern part of the region attributed to the event was visited by scientists in 1927. The center of the forest fall with coordinates 60.9 N, 101.9 E is frequently called the epicentre of the Tunguska explosion.

Various conjectures were soon offered in 1908 to explain the nature of the event. The most popular were a meteorite fall, ball lightning (or its formation) and an earthquake. Since that time more than a hundred explanations have been proposed, and the origin of the event is still disputed (Anonym., 2002).

Little has been published on the geophysical circumstances of the event until now. Rare exceptions are an accompanied geomagnetic disturbance, and the "bright sky" phenomenon (Vasilyev, 1998).

In this work other aspects of the geophysical situation are investigated, especially tectonic and meteorological activity.

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For convenience, in the text below after some geographical names, distances from the Tunguska epicenter and azimuths in degrees from the epicenter, measured from the north to the east are given in brackets (Vasilyev et al., 1981), for example "Mutorai River (54 km, 244 deg)".

2. Geophysical Circumstances of Tunguska Event

Here it will be shown that the event took place during a remarkable and rare combination of geophysical factors on regional and in part, on larger scales.

2.1. Tectonic aspects of Tunguska event

From a geological perspective, the Tunguska event occurred in a rather remarkable place in the southern part of the Siberian platform. It was the place of one of the most powerful volcanic episodes in Earth history 250 million years ago (Sapronov, 1986), a former "hotspot". The region is rich in various gas/oil, and ore deposits, including rare-earth-elements, and platinoids. There are kimberlites in the region too. The upper mantle in this region has anomalous speeds of seismic waves (Pavlenkova and Solodilov, 1997).

The Tunguska epicenter is right in the middle of the ancient volcanic crater, which after its discovery in 1972 got the name "Kulikovskii". This volcano is a part of Khushminskii tectono-volcanic complex (Sapronov, 1986).

The Tunguska event occured in the "bundle" (intersection area) of several powerful tectonic faults in the region (see Figure 1).

Interestingly, Eromenko (1990, p.63) writes about one the most prominent faults, the Beryozovsko-Vanavarskii tectonic fault, that part of it goes along the trajectory of the "Tunguska meteorite".

Naumkin (1989) has discovered that some tectonic faults in the area of the Tunguska epicenter were formed as early as in the Neogene.

The Baikal rift region is known as a region of rather high seismic activity. The region of the Tunguska event, which is adjacent from the north and the north-west to the Baikal rift, has a much lower level of seismicity. During the last several decades of seismical monitoring no earthquakes have been detected in the area of the Tunguska epicenter (but the closest seismic stations are several hundred kilometres away, at least).

All the earthquakes registered in the region of the Tunguska event are to the south of the Tunguska epicenter, with the majority not far from Lake Baikal, and just a few farther to the north.

Nevertheless, in 19th and early 20th centuries many earthquakes were reported rather far to the north of Lake Baikal (Nikiforov, 1939). Moreover, we (Ol'khovatov, 1997, p.50) have discovered a couple reports dating to the middle of 19th century on earthquakes in Preobrazhenskoe settlement (347 km, 103 deg),

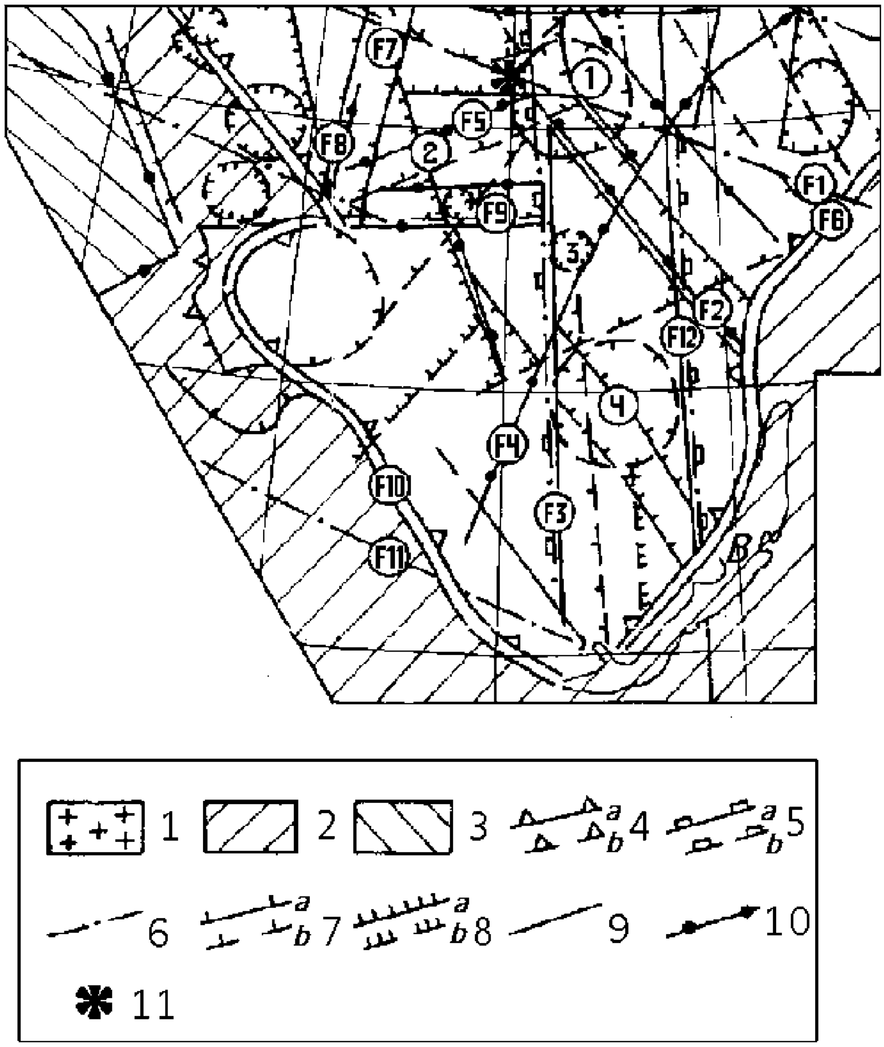

Figure 1. A map of some geological features of the Tunguska region (adapted from Figure 15, application of (Eromenko, 1990)) B – Lake Baikal; 1 – the Siberian platform basement outcrops; 2 – the plicated frame of the Siberian platform; 3 – the West Siberian plate; 4–10 – the tectonic faults from space data; 4 – the frame faults, seperating the Siberian platform (a – distinctly seen, b – less distinctly seen); 5 – the interplatform frame faults, separating the plicated regions of the basement with different ages (a – distinctly seen, b – less distinctly seen); 6 – the transregional faults; 7 – the regional faults (a – distinctly seen, b – less distinctly seen); 8 – other faults (a – distinctly seen, b – less distinctly seen); 9–10 – the tectonic faults from geophysical data; 9 – the frame faults; 10 – the regional faults; 11 – the Tunguska epicenter; LINEAMENT FAULTS: F1 – the Beryozovsko-Vanavarskii fault; F2 – the Norilsko-Markovskii fault; F3 – the Angaro-Khetskii fault; F4 – the Angaro-Viluiskii fault; F5 – the Chadobedsko-Irkineevskii fault; F6 – the Baikalskii fault; F7 – the Chadobedsko-Tyichanskii fault; F8 – the Irkineevsko-Nordvikskii fault; F9 – the Nizshneangarskii fault; F10 – the Prisayanskii fault; F11 – the Sverdlovsko-Irkutskii fault; F12 – the Baikalo-Taimyirskii fault; CIRCLE STRUCTURES: 1 – the Vanavara circle structure; 2 – the Chadobedskaya circle structure; 3 – the Verkhnekatangskaya circle structure; 4 – the Angaro-Lenskaya circle structure.

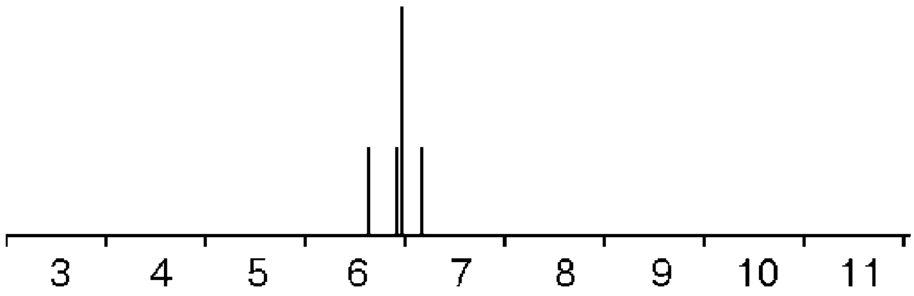

Figure 2. The time-sequence of earthquakes (vertical lines) in the Lake Baikal region and surroundings from March 1908 (3) to November 1908 (11) taken from (Nikiforov, 1939). The seismic manifestations associated with Tunguska event are marked by enlarged height of the vertical line.

and golden mines (461 km, 246 deg), i.e., rather close to Tunguska epicenter's latitude.

To check for seismic (tectonic) activity in the Tunguska event region, we have investigated a catalogue of earthquakes (Nikiforov,1939), and "Bulleten Postoyannoi Tsentralnoi Seismicheskoi Komissii" for 1908 (Levitskii, 1910) and also for previous years. The purpose was to estimate the number of local earthquakes in the Tunguska event region during those years. To select only earthquakes in the Tunguska event region, earthquakes reported just to the north of Lake Baikal (excluding its shore) were taken (earthquake epicenters were rarely pinpointed in those years). The result is the following. In 1906 just 1 earthquake was registered, in 1907 the number was 2, in 1908 – 6 (including the one associated with Tunguska event), in 1909 – 0, in 1910 – 1. In other words, in 1908 an upsurge of seismic activity took place in the area of the Tunguska event.

The latter result is in agreement with the data for the whole Baikal rift and its surroundings seismicity (Nikiforov, 1939), which shows 10 earthquakes in 1908, and just 1 in 1909, and 1910, and an absence of detected earthquakes in 1911.

The distribution of earthquakes in the Baikal rift region and surroundings within the year 1908 is also remarkable and is shown on Figure 2.

The earthquakes clustered around the Tunguska one. In other words, there was a peak of regional seismic activity at about June 30, 1908.

Interestingly, at about the time of the Tunguska event an unusual phenomenon was discovered near Ust'-Kut settlement (513 km, 152 deg): a hot "salted"

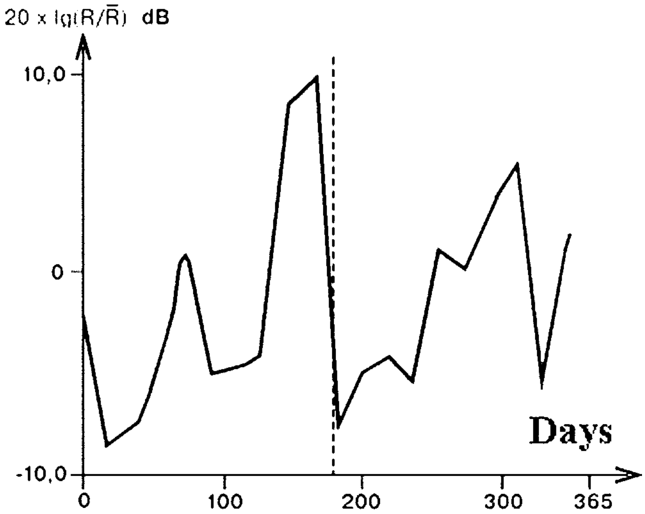

Figure 3. Radius of the Earth axis polhode (R) normalized to its annual average meaning in 1908 in decibels (dB). The horizontal line marks days from beginning of the year 1908. A dashed vertical line marks the date of the Tunguska event.

spring with various chemical elements, which was absent in the previous summer (Vasilyev, 1981, p. 28).

There is also evidence of activation of tectonic processes at the time not just in the Baikal rift, and the southern part of the Siberian platform, but also on a larger (global?) scale. The evidence is following.

We searched through data on the position of the Earth axis of rotation, given in Kotlyar and Kim (1994), together with the "momentary" polhode radius of the Earth axis trajectory on the Earth surface (in other words, locus of the instantaneous intersection of the Earth's axis with the Earth's surface). The data in Kotlyar and Kim (1994) are given with an interval (step) of 0.05 year. Their graphics (Kotlyar and Kim, 1994, p. 19) has revealed that between 1908.35 (i.e., May 8) and 1908.40 (i.e., May 26) a strong increase of the polhode radius took place. Then, between 1908.40 and 1908.45 (i.e., June 14) it stabilized. And finally from 1908.45 to 1908.50 (i.e., July 2) the strongest decrease of the polhode radius has occurred. It is shown on the Figure 3, adapted from (Kotlyar and Kim, 1994, p. 19).

The rate (versus time) of the relative change of the polhode radius for this period between June 14 and July 2 1908 was the largest not only in 1908, but also for the whole period of 1907–1910.

It is interesting, that volcanic activity probably gravitated to some of the above-mentioned dates of polhode variations. At the first half of May 1908 the strongest activity since 1894 of the Kilauea volcano began (Anonym., 1908a). On May 10, 1908 on the Savaii island in the Samoan group, the most powerful for the whole island's history volcanic eruption commenced (Anonym., 1908b). Since April 1908 fumarolic activity of the Erebus volcano, which slept since 1900, was increased

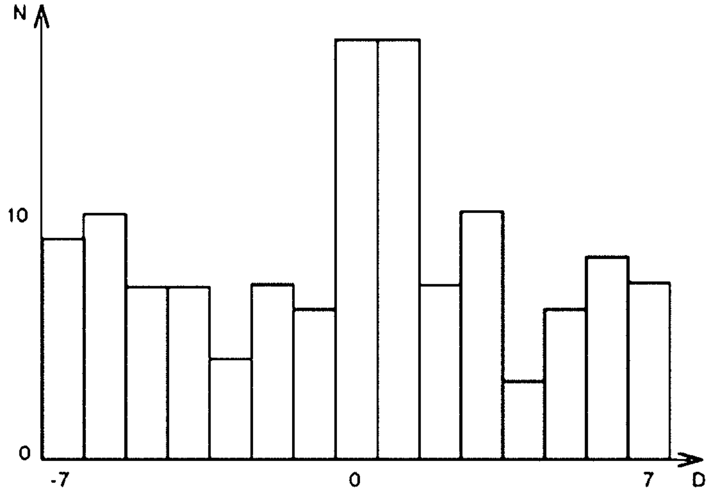

Figure 4. Number (N) of earthquake reports all over the Earth per day (D) according to their universal times, a week before and a week after the Tunguska event, where June 30, 1908 is a "zero" date. Initial data is taken from (Sieberg, 1917).

with significant upsurge on June 17 (Newhall and Dzurisin, 1988). Also on April 29 a remarkable eruption of the Etna volcano, which slept for 15 previous years occurred (Anonym., 1908c).

Remarkably, the NOAA/US Geological Survey Earthquake Data Base "Significant Earthquakes World Wide" shows that from the spring to the autumn of 1908 there was an unusual absence of large earthquakes. Data of (Sieberg, 1917) also shows a decrease of the total number of earthquake reports in summer 1908, so the seismic energy release that year was one of the lowest for the 20-th century. But on the other hand, on June 30 and July 1 the number of registered earthquakes was increased. It is shown on Figure 4 (data on the earthquakes was taken from (Sieberg, 1917)).

So there is strong evidence of significant seismic activity in the Tunguska event region, and possibly even large-scale (global?) disturbances in the Earth interior at about the Tunguska date.

2.2. Meteorological circumstances of Tunguska event

It is important, that besides tectonic, there were also numerous other geophysical peculiarities in that period of time on a regional, as well as, a much larger scale (Ol'khovatov, 1997, 1998; Vasilyev, 1998).

There were some peculiarities in global atmospheric circulation at about the Tunguska date. In June 1908 a high barometric maximum was lying in the north (the Arctic region), and the winds were blowing from the north, and cyclones over Siberia in June were much deeper than usual, which led to significant increase of air pressure gradients (Kozkhenkova et al., 1963).

Another peculiarity was an unusual warm (hot) weather in Europe and especially in Siberia in the second half of June. Together with the small number of thunderstorms it led to drought in some regions.

At the beginning of July the situation sharply changed. There was a strong increase in thunderstorm activity in Europe, and especially in the western part of Russia and Siberia. Powerful thunderstorms took place. For, example in the Perm' province, Russia in July the quantity of precipitation was a record for the whole 70 previous years of measurements. The northern (Arctic) area of high pressure sharply decreased in dimensions.

These meteorological peculiarities were particularly prominent in the region of the Tunguska event. We have discovered that it was a change from good weather to a bad weather right on June 30, 1908 (expecially on the morning). We have used data from 9 meteorological stations situated no farther than 1000 km from the Tunguska epicenter (but the closest was 500 km away). The data were averaged between the stations for better statistics. A result shows that Tunguska was inside a "lacuna" in cloudiness, and the averaged daily cloudiness level shows strong increase of cloudiness after Tunguska (see Figure 5).

A further striking feature is that the Tunguska event occurred exactly at the time of a maximum of atmospheric pressure in the region. This is best seen in data from the Irkutsk station, which had a log of data with sampling rate every 3 hours (see Figure 6). And the maximum of the air-pressure upsurge was between 6 and 9 a.m. local time (UT + 6h.57 min.), while the Tunguska explosion was a little bit later 7 a.m.

Unfortunately, little is known of the meteorological data at the Tunguska epicenter area. While in the areas closest to the epicenter witnesses (Evenks) usually spoke about clear weather at the time of the Tunguska event, but others said that the weather was not so good. Here are several interesting accounts (Vasilyev et al., 1981) below. Also, please, pay attention to the remarkable "red colour" and on the sequences of the phenomena.

– Nastya Genkoul' (river Khushma (32 km, 125 deg)). There was good weather, then suddenly it rained, strong wind commenced. Trees were uprooted.
– Aksenova O. (upper reaches of the Mutorai river (54 km, 244 deg)). There was a good weather on the early morning. Then wind commenced. It became dark, as before a rain. The ground got red colour, and a strong thunder struck. She did not see anything on the sky.
– Andreeva E. Ya. (upper reaches of the Severnaya Chunya river (137 km, 84 deg)). There was a windstorm in the morning, then there was a strong thunder, and the ground shook. After the thunder, the sky got red colour towards Vanavara.
– Dmitrieva M.V. (a little bit to the north of the mouth of Kimchu river (96 km, 305 deg)). On the early morning the weather was not rainy, but gloomy. The sky was covered with high clouds. No wind. Then there were "explosions", a

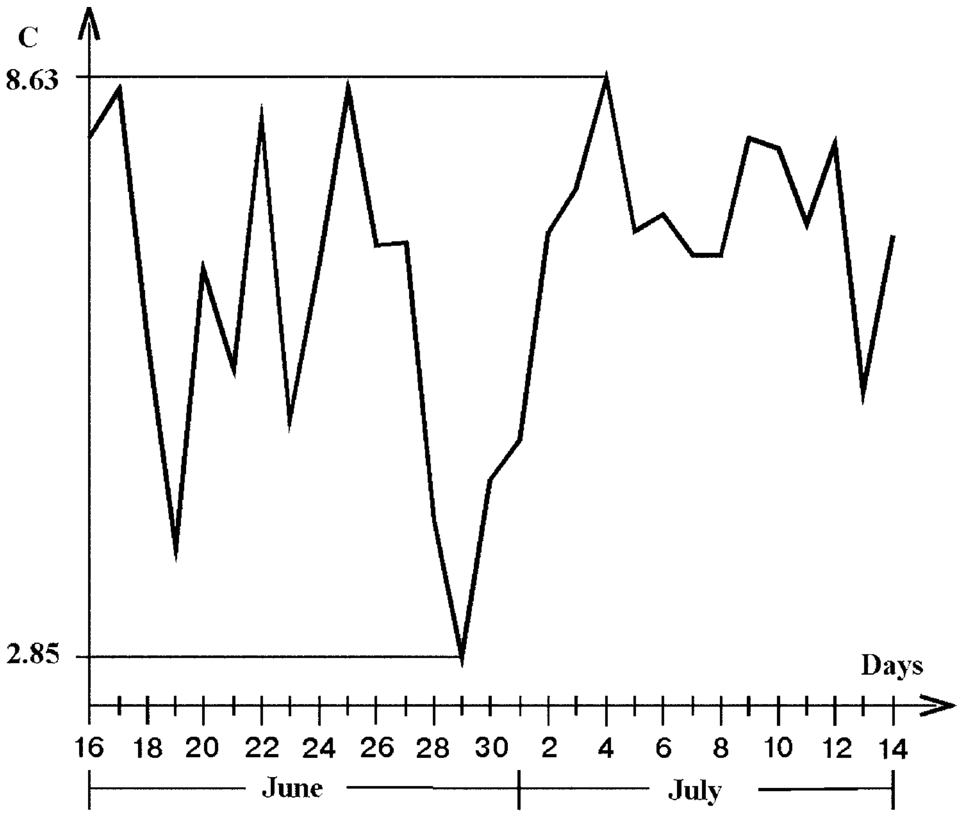

Figure 5. Daily cloudiness level (C) averaged over 9 meteorological stations in the Tunguska event region for June 16–July 14, 1908. C=0 means clear sky, C = 10 means maximum cloudiness (overcast).

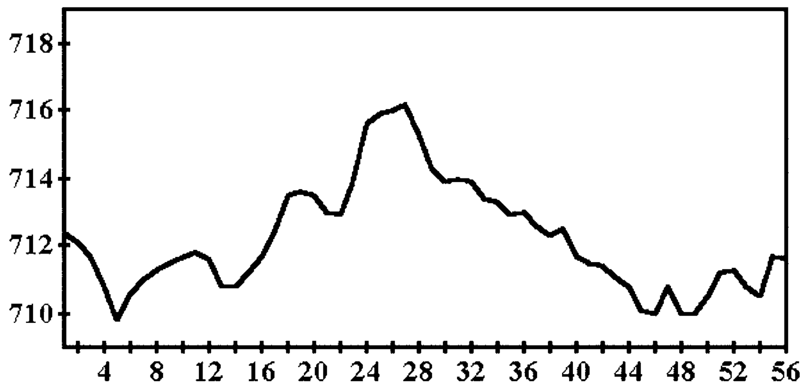

Figure 6. Airpressure (mm. Hg) at Irkutsk's meteorological station from June 27 to July 3, 1908. Numbers on the horizontal line mark numbers of 3-hours counts since 3 am local time June 27, 1908. Count 26 means 6 am, and count 27 means 9 am June 30, 1908.

strong wind, and an earthquake at once. Also after the explosions, the sky got red colour, and then the red colour gradually moved to the west.

The closest to the Tunguska epicenter Kezhma meteorological station (214 km, 193 deg) registered at 9 pm local time on June 29 cloudiness 3. At 7 am local time June 30 (i.e., at about the time of the Tunguska) cloudiness was 4, and at 1 pm local time June 30 (i.e just 6 hours after Tunguska) – cloudiness was 10, i.e., maximum.

Similar situation was in the town of Kirensk (491 km, 132 deg), where on June 30 at 7 am local time cloudiness was 0, and 9 at 1 pm local time (also a strong wind was registered by the Kirensk's meteorological station on June 30). At about 2 pm local time a thunderstorm with hail was between Kirensk (491 km, 132 deg) and Nizhne-Karelino settlement (465 km, 133 deg) (but closer to Kirensk).

Interestingly, in the late 1920s, while discussing the Tunguska event in the Soviet Academy of Science, the outstanding Soviet meteorologist Prof. Mul'tanovskii B. drew attention to a possibility of cyclonic air mass movement in the area on the date of Tunguska event.

Conducted in Dyomin et al.(1984) statistical analysis of witness's accounts has revealed that Tunguska event was accompanied by various meteorological phenomena, including strong wind (windstorms), haze, fog, temperature changes, thunderstorms, whirlwinds.

In other words the Tunguska event indeed took place during a period of strong meteorological peculiarity, associated with sharp weather "worsening".

2.3. Other geophysical peculiarities

There is also other evidence of a peculiar geophysical situation at the time of the Tunguska. On June 29 the "Alps Glow" phenomenon was registered in Austria (Vasilyev et al., 1965). Remarkably, it was the only registration of this phenomenon for the whole 1908 summer.

Interestingly, that exceptional sky glow (aurora?) was observed by the Sir Douglas Mawson expedition in the Antarctic just 7 hours before Tunguska (Steel and Ferguson, 1993), despite rather low geomagnetic activity.

There was also a report on disturbances of telegraph lines near Prague at about June 30 (Brauner, 1908).

It is important to note that on June 30 the appearance of a rather large solar protuberance was discovered (Vasilyev et al., 1965). We also suspect a powerful solar proton event in late June, 1908 (Ol'khovatov, 1997).

Interestingly, the famous "bright nights" phenomenon, associated with Tunguska commenced before June 30 in reality (Denning, 1908; Vasilyev, 1998).

Detailed investigation of the data on atmospheric spectral transparency obtained by the Astrophysical Observatory of the Smithsonian Institution revealed the existence of some anomalies (Nikolskii and Shul'ts, 1990). Despite that the interpretation of the data is very complicated and possibly partly ambiguous, the results are very interesting and worth of mention. For example, they have discovered that since approximately mid-May, 1908 there was additional periodic absorption probably caused by clouds of dust in the stratosphere with mass in the order of 3 million tons, which were later misinterpreted as dust of the "Tunguska spacebody" (Nikolskii and Shul'ts, 1990). In their opinion, the Tunguska event added no dust, but was probably associated with an upsurge of water vapour in the atmosphere of order 1700 millions tons in total. However the upsurge commenced on June 19, 1908 and lasted until about August 8, 1908, reaching the condensed water vapour level of 2.6 cm. The authors (Nikolskii and Shul'ts, 1990) wrote that they had not found similar peculiar behaviour at other seasons.

Remarkably, a Greenland ice layer corresponding to the spring-summer of 1908 contains an extremely large quantity of terrestrial dust (probably soot, in general) (Legrand, et al., 1995).

3. Discussion

Thus there was indeed a specific geophysical situation in association with the Tunguska event, including remarkable seismic and atmospheric activity in the area of Tunguska event, and partly on larger scales.

Note that if any of the geophysical peculiarities taken separately can be just of accidental coincidence with the Tunguska event, a possibility that they all together were just an accidental coincidence is very unlikely.

Remarkably, all (at least, known to us) phenomena associated with Tunguska occur in various forms in association with geophysical processes.

Keeping in mind problems with a spacebody interpretation of Tunguska (Ol'khovatov, 1997, Vasilyev, 2000), in our opinion the most likely explanation of the event is that the Tunguska event was of geophysical origin, probably caused by some poorly understood coupling between subterranean (tectonic) and atmospheric phenomena (Anonymous, 2002), with some possible input of solar activity.

This work was a private research and has nothing to do with the author's affiliation. More detailed info can be read at http://www.geocities.com/olkhov.

References

Anonymous: 1908a, *Science* **28**, 19.
Anonymous: 1908b, *Nature* **78**, 155.
Anonymous: 1908c, *Nature* **78**, 435.
Anonymous: 2002, *Science* **297**, 1803.
Brauner, B.: 1908, *Nature* **78**(2019), 221.
Denning, W. F.: 1908, *Nature* **78**(2020), 247.
Dyomin, D. V., Dmitriev, A. N., and Zhuravlev, V. K.: 1984, in *Meteoritnye issledovaniya v Sibiri*, Nauka, Novosibirsk, pp. 30–49 (in Russian).
Eromenko, V. Ya.: 1990, *Kosmicheskie Snimki Pri Izuchenii Morfotektoniki i Geodinamiki Sibirskoi Platformy*, Nedra, Leningrad, 160 pp. (in Russian).

Kotlyar, P. Ye., Kim, V. I.: 1994, *Polozhenie polyusa i seismicheskaya aktivnost' Zemli. Atlas*, Nauka, Novosibirsk, 123 pp. (in Russian).

Kozkhenkova, Z. P., Brok, V. A., Fedyushina, L. P. et al.: 1963, Sinoptiko-meteorologicheskie usloviya leta 1908 g., in: *Problema Tungusskogo meteorita*, Tomsk State Univ., Tomsk, pp. 179–186 (in Russian).

Legrand, M., De Angelis, M., Cachier, H., and Gaudichet, A.: 1995, in R. J. Delmas (ed.), *Ice Core Studies of Global Biochemical Cycles*, Springer-Verlag, pp. 347–360.

Levitskii, G. (ed): 1910, *Bulleten Postoyannoi Tsentral'noi Seismicheskoi Komissii za 1908 god*, Sankt Peterburg, (in Russian)

Naumkin, A. N.: 1989, *Vestnik Moskovskogo Universiteta*, seriya 4(5), 69–72 (in Russian).

Newhall, C. G. and Dzurisin, D.: 1988, 'Historical Unrest at Large Calderas of the World', *Bull. US Geol. Survey* **2**(1855), 1006.

Nikiforov, P. M. (ed.): 1939, 'Katalog zemletryasenii na territorii SSSR. Sibir', *Trudy seismologicheskogo instituta* **2**(89a), 39 (in Russian).

Nikolskii, G. A. and Shul'ts, E. O.: 1990, *Meteoritika* **49**, 202–217 (in Russian).

Ol'khovatov, A. Yu.: 1997, *Mif o Tungusskom meteorite. Tungusskii fenomen 1908 goda – zemnoe yavlenie*, ITAR-TASS-Assotsiatsiya Ekologiya Nepoznannogo, Moscow, 128 pp. (in Russian).

Ol'khovatov, A. Yu.: 1998, *Science in Russia* **3**, 45–49.

Ol'khovatov, A. Yu.: 2000, *Record for the IEEE International Conference on Plasma Science*, June 4–7, 2000, New Orleans, USA, p. 242.

Pavlenkova, G. A. and Solodilov, L. N.: 1997, *Fizika Zemli* **3**, 11 (in Russian).

Sapronov, N. L.: 1986, *Drevnie Vulkanicheskie Struktury Na Yuge Tungusskoi Sineklezy*, Nauka, Novosibirsk, 104 pp. (in Russian).

Sieberg, A.: 1917, *Catalogue regional des tremblements de terre 1908, Part A*, Publications du Bureau Central de L'Association internationale de Sismologie, Strasbourg, 214 pp. (in French).

Steel, D. and Ferguson, R.: 1993, *Australian Journal of Astronomy* **5**(1), 1–10.

Vasilyev, N. V., Zhuravlyev, V. K., Zhuravlyeva, R. K. et al.: 1965, *Nochnyie svetyasshiesya oblaka i opticheskie anomalii, svyazannye s padeniem Tungusskogo meteorita*, Nauka, Moscow, 112 pp. (in Russian).

Vasilyev, N. V., Kovalevskii, A. F., Razin, S. A. et al.: 1981, *Pokazaniya ochevidtsev Tungusskogo padeniya*, registered VINITI 24.11.81, N 10350-81, Moscow, 304 pp. (in Russian).

Vasilyev, N. V.: 1998, *Planet. Space Sci.* **46**, 129–150.

Vasilyev, N. V.: 2000, *Tungusskii Vestnik KSE* **11**, 5–14 (in Russian).