Research of transient events in the upper atmosphere measured by Universitetsky-Tatiana-2 satellite far from lightning activity

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MSU satellite Universitetsky-Tatiana-2 was launched in 2009 and it was aimed to study transient luminous events (TLE) in the atmosphere. During three months of its operation more than 2000 flashes in UV and IR range of wavelengths were measured. In the earlier research it was found out that there are some events which occur far away from the cloud cover. This work is devoted to the research of such events: of their frequency, geographical distribution and possible hypothesis of their origin. Among all events, measured in November, 2009 it was found 110 flashes which occurred more than 1000 km from the closest lightning during one minute of measurement. This events have various temporal structure (from 1 to 128 ms) and photons number ($2\cdot10^{20}$ – $8\cdot10^{23}$). Some of them have a thunderstorm in the conjugate point of magnetic field.

1. Introduction

All known types of Transient Luminous Events (TLE) appear in conjunction with regions of thunderstorm activity.

There are several measurements of unusual TLE which occur far from thunderstorm regions. The most recent example of such measurement is described in [1]. TIGER (Transient Ionospheric Glow Emission in Red) event was observed from space shuttle during MIEDEX sprite campaign. This transient (shorter than 33 ms) emission was delayed by 0.23 seconds to a preceding visual lightning flash which was horizontally displaced at >1000 km from the event. There are earlier observations of unusual atmospheric flashes. Fast atmospheric pulsations (1 ms) were reported by Ogelman in 1973 [2], the similar events not associated with lightning were observed by Nemzek and Winkler [3].

Authors discuss three hypothesis of the possible origin of unusual TLE: the precipitation of relativistic electrons from the radiation belts, acceleration of electrons in the discharge on conjunction point of magnetic field and their further precipitation and also scattered light of very distant lightning. Not one of the hypotheses has sufficient experimental evidence.

It is also worth noticing that authors of paper [4] in measurements of gigantic jet found the lack of lightning preceding events although they occurred over an area of thunderstorm

During measurements of fast UV and IR flashes on board Universitetsky-Tatiana-2 (Tatiana-2) satellite there were found that some events occur far from cloud coverage and thunderstorm regions. In this work we report preliminary results of search and analyses of Tatiana-2 satellite events displaced more than 1000 km from the nearest lightning.

2. Universitetsky-Tatiana-2 satellite UV and IR detector

On board Tatiana-2 satellite the detector of UV and IR radiation was launched in September 2009 and operated during three months on the orbit. The detector consists of two photomultiplier tubes (PMT) Hamamatsu R1463 with readout electronics. Field of view is limited by the collimator and is ~16° for each of the PMT , which corresponds to the area of observation: $7\cdot10^4$ km^2. The detector measure fast flashes in the UV (300 - 400nm) and infrared (610 - 800 nm) wavelengths. Direction of observation - the nadir. The event information is written in the form of two codes: ADC code (N) and the code on the photomultiplier high voltage (M), since device adjusts to background lighting conditions by changing of high voltage on the photomultiplier.

For more detailed description of the detectors electronics and first data analysis see [5].

For the further data analysis it is important to notice that UV detector on board Tatiana-2 satellite can record only one the most powerful events during a minute of observation (waveform length: 128 ms, time step: 1 ms).

To select events from Tatiana-2 satellite data which occur far from current lightning activity, we used data about lightning location of terrestrial network WWLLN. This study was performed to search for matches in the databases of Tatiana-2 and WWLLN for one minute prior to the time of recording waveform of the flash. It is important to notice that efficiency of WWLLN was growing

during the development of a network and depends from lightning power and type. In 2009 the detection efficiency of CG lightning was near 10 % [6].

3. Results and discussion

We analyzed all events from November 2009 measurements of Tatiana-2 and found out 110 (12 %) which horizontally displaced more than 10˚ by latitude and longitude (1100 km). In such a large region in case of thunderstorm a detectable for WWLLN number of lightning should occur. It means that probability of lightning induced event measured by Tatiana-2 is very small. So, we consider these events as "remote from lightning". The geographical distribution of these events is shown on the figure 1. There is no obvious relation with well known thunderstorm regions. Mostly events are concentrated near equatorial region and there is excess between 40˚ and 60˚ of latitude.

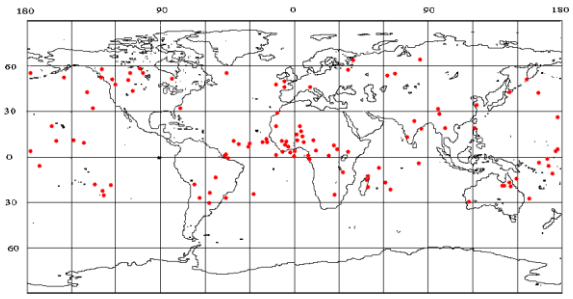

Fig. 1. Geographical distribution of UV flashes far from thunderstorms.

We analyzed the types of waveforms that occur outside the thunderstorm area. It turned out that they are quite diverse. The most part constitute the single short bursts of 1-2 ms duration, but there are also long waveform (up to 128ms) both single and with a periodic structure, the events with complex repetitive impulse structure and series of short (1 ms) pulses. Two examples of events are shown on the figure 2.

It is important to notice that these events are relatively powerful. The photons number, produced in the atmosphere is distributed form $2{\cdot}10^{20}$ to $8{\cdot}10^{23}$.

We started to check existing hypotheses of unusual TLE origin and we separated events which have thunderstorms at the same time but in the conjunction point of magnetic field. We found only 10 candidates and only few of them are sufficiently faint and short as predicted by [7].It is interesting to note that in some experiments aimed directly at the search of these events was not detected any of them [8].

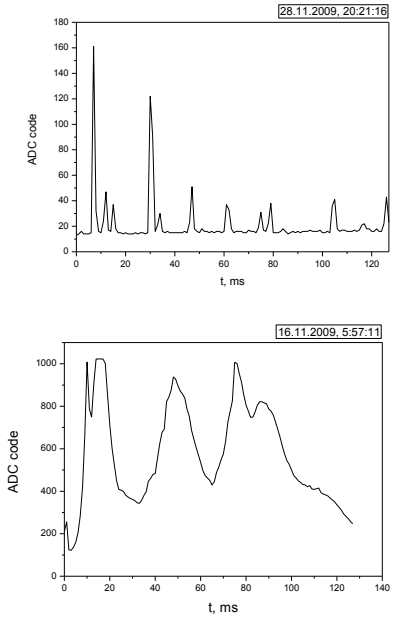

Fig. 2 Examples of waveforms of faint (upper panel) and bright (bottom) TLEs far from thunderstorm.

3. Conclusions

We started the joint analysis of Tatiana-2 satellite and WWLLN databases. And found out that 12 % of measured by satellite transient UV and IR flashes occur far (>1000 km) from lightning and thunderstorm regions. The further analysis of the whole satellite database and origin hypotheses will be carried out.

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4. References

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