Chibis-M observations of VHF and VLF/ELF emissions from lightning discharges.

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Great number of VHF and VLF/ELF emissions were observed during two years of the Chibis-M mission operation. Spectral analysis has revealed a variety of time-frequency patterns of signals, many of which are to be interpreted. About 300 VHF events were classified as compact intercloud discharges (CID). Along with other types of emissions, those with unusually long duration (~150 μs) were detected. VHF measurements were accompanied by whistler mode waves recordings, showing strong correlation of VHF events with lightning discharges. In this paper we present classification of events, their characteristics and geographical and diurnal variations.

1. Chibis-M mission

The Chibis-M microsatellite was launched into a circular orbit on January 25, 2012 by means of International Space Station facilities. The main goal of the mission is to study lightning activity via the recording of electromagnetic signals in broad frequency band. The microsatellite carries a radio-frequency analyzer (RFA), ultraviolet and infra-red detectors, a fast optical camera, VLF detector, and gamma and X-ray detector. Because of deployment procedure the Chibis-M satellite has an inclination of 52°, covering middle and low latitudes, which along with unique payload makes Chibis-M opportune tool for comprehensive study of lightning activity.

Lightning discharges known to be the source of VLF (3-30 kHz), LF (30-300 kHz), MF (0.3-3 MHz), HF (3-30 MHz), VHF (30-300 MHz) and UHF (>300 MHz) electromagnetic waves. The most famous lightning related phenomena at VLF frequency band are atmospherics, which propagate in the Earth-ionosphere waveguide, and whistler mode phenomena, which propagate in magnetospheric plasma. Having VLF detector onboard Chibis-M and cooperating with lightning location network on the ground, it might be possible to indicate the lightning discharge, that causes detection at other Chibis-M instruments.

As lightning discharges by nature have stochastic time of occurrence, a trigger system of event registration onboard the spacecraft was realized. At the testing stage of the mission it was admitted that the instrument which initiates trigger for the complex should be RFA. This instrument measures electric field in frequency range from 26 MHz to 48 MHz.

2. Observations

A variety of signals were detected onboard Chibis-M. In this paper we present only those from VHF and VLF detectors. Preliminary classification of the signals were made and physical characteristics of signals were determined. The most common signal at VHF frequency band are single pulse, double pulses (which are referred as Trans-Ionosheric Pulse Pairs (TIPP) [1], or Narrow Bipolar Event [2]), trains of pulses with total duration of dozens or hundreds of microseconds, and long duration unstructured broadband emission with peak energy at about 30 MHz (see Fig. 1). One pulse duration is about 5 μs (accuracy is limited by applied Fourier transform window).

An analysis of signal localization was made. For example, TIPP shows no significant latitudinal dependence, having almost equal change to happen at the middle latitudes and near the equator. On the contrary, TIPP occurrence strongly depend on longitude and local time, which is in agreement with previous experimental data [3]. Longitudes of TIPPs coincide with longitudes of the regions with high lightning activity. Local time distribution has two peaks around 3 p.m. and just after midnight. Only half of TIPP recordings accompanied by ultra-violet and infra-red emissions. Most of the events were observed over the west coast of Africa, over Maritime Southeast Asia, and near the Central America.

VLF detector demonstrates records with well-known whistler mode waves, including ion-cyclotron whistlers, along with "swallow-tailed" [4] and "spiky" whistlers [5].

3. References

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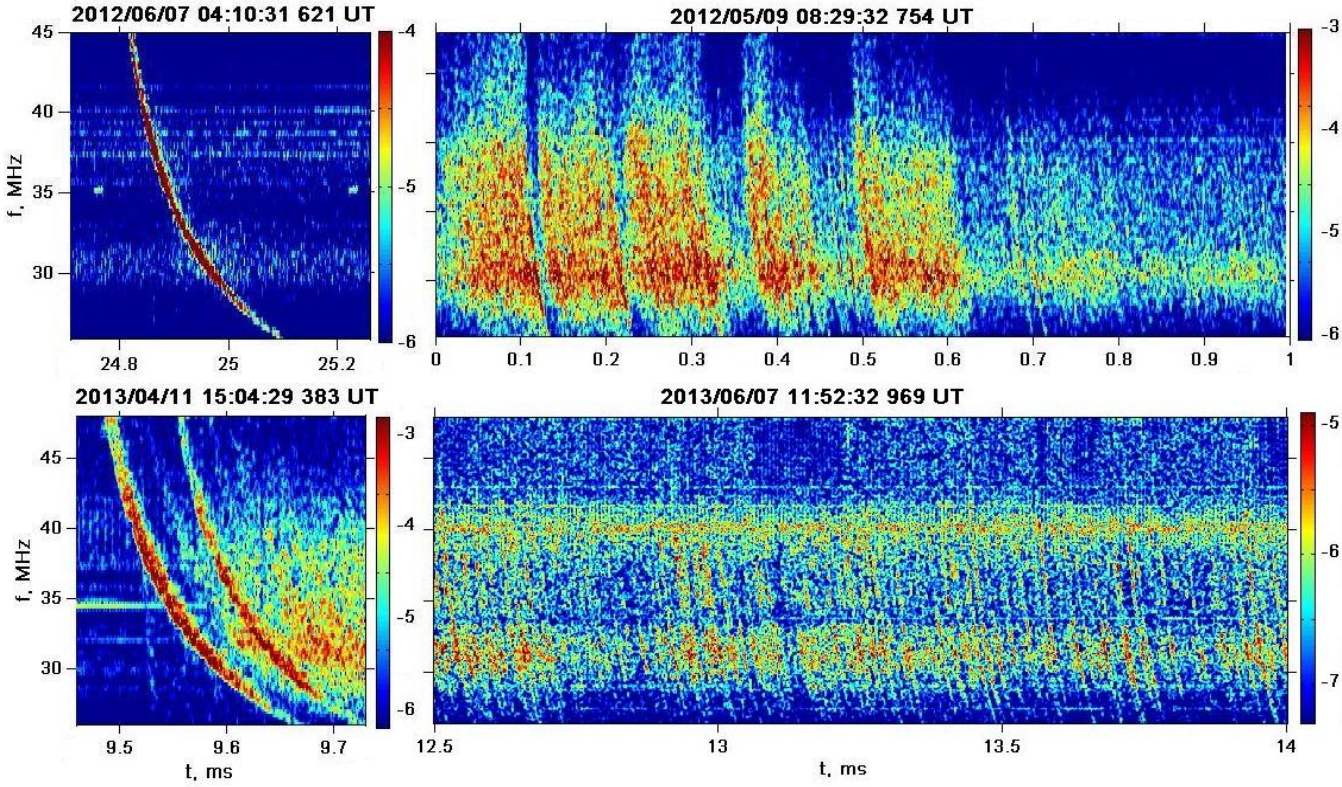

Figure 1. Examples of VHF signals recorded by Chibis-M: single pulse (left top), train of pulses (right top), double pulses (left bottom) and multiple pulses (right bottom).