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Study of Ionospheric Effects and Earthquake Precursors Using Radio Engineering Methods

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Abstract. Features of the remote sensing of seismic disturbances in the lower ionosphere are considered according to observation data of lightning electromagnetic signals passing over the earthquake epicentre, in Yakutsk. The technique has the ability to scan a large seismically active region or even several regions directly from one point, though in some azimuths there are limitations due to insufficiently high lightning activity. The location of the signal receiving point allows you to explore such seismic regions Kamchatka, Japan, China, the Philippines and Indonesia, South Yakutia, and Baikal, provided there is a good thunderstorm activity.

1. Introduction

VLF-electromagnetic signals propagating in the Earth-ionosphere waveguide undergoes amplitude-spectral variations when disturbances occur in the lower ionosphere (the upper boundary of waveguide). The sources of these disturbances are solar and geomagnetic activity, meteorological and lithospheric disturbances, such as earthquakes or volcanic eruptions. The fact that the ionosphere is very sensitive to seismic impacts is noted, for example, in [1]. This factor makes it possible to attract VLF radio signals for remote monitoring of seismic disturbances in the lower ionosphere. In our research, natural signals i.e. electromagnetic signals from thunderstorms, are used for remote monitoring of parameters of the lower ionosphere over seismically active regions [2, 3]. The location of the registration point allows remote monitoring of the parameters of the lower ionosphere over such seismically active regions as Kamchatka, Japan, China, the Philippines and Indonesia, South Yakutia, Baikal and European regions.

2. Data and measurement techniques

The paper uses data obtained mainly with a single-point lightning direction finder-rangefinder developed at ShICRA SB RAS. The recording system used allows us to study both local thunderstorm activity [4] and thunderstorms in the world's thunderstorm centres [5]. The lightning direction finder-rangefinder consists of a system of antennas and a recording part. A universal antenna system is used, which makes it possible to monitor both local thunderstorms and planetary thunderstorms, depending on the threshold set for recording signals of natural radio noise in the VLF range. The antenna system includes two crossed magnetic antennas and one electric vertical one. Structurally, a three-meter electric antenna with a cone attachment (to increase the antenna capacity) is set up on a seven-meter metal mast on an insulator. Two square-shaped shielded frames (the effective area of the frame is 360



m2) are placed on the same mast. There are several radio engineering methods for remote monitoring of the lower ionosphere parameters. Mainly, the signals of radio stations are used, the advantage of which is that the signal parameters in the source are known and the signals at the registration point can be used to study the waveguide parameters. However, the VLF signal transmitters of radio stations are stationary and monitoring can only be carried out from the direction of signal reception. The use of electromagnetic signals from lightning discharges makes possible to carry out the azimuth scanning of seismically active regions. The disadvantage of presented method is that it is impossible to conduct monitoring in the absence of thunderstorm activity behind earthquake epicentres. However, the method can be used in conjunction with other research to improve the quality of forecasting and study of lithospheric-ionospheric relations.

The main parameter analysed is the average hourly amplitude of atmospheric signals received at the Yakutsk from certain directions. As is known, changes in the signal amplitude should be expected if the area of disturbances on the path of their propagation is located in the ellipsoids of the first Fresnel zones. Therefore, for analysis, we select those atmospherics whose paths/routes are located within the specified zones centered in azimuth of the earthquake epicentre. The average amplitude is calculated for atmospherics whose signal sources are lightning discharges located behind the epicentre. In this case, the sources are reduced to a single distance (the distance to the epicentre), taking in the first approximation an inversely proportional dependence of the amplitude on the distance

3. Results

The first analyzed earthquake occurred in Japan (35.687° N, 140.695° E) on March 14, 2012. Magnitude of the earthquake was 6, and the focus was at a depth of 10 km. Distance from the epicenter to the point of receiving the signals (Yakutsk) was about 3000 km, and the main sources of signals of atmospherics in azimuth to the epicenter lies at distances 4200-5600 km from the receiving point. Thunderstorm was located above the ocean surface, and therefore the amount of atmospherics for hourly intervals averaging was not so much what is usually observed over land. The day-to-day variations of the amplitude of thunderstorm signals determined for the night conditions (15-16 UT), passed over the area of the earthquake epicenter, are shown in Figure 1.

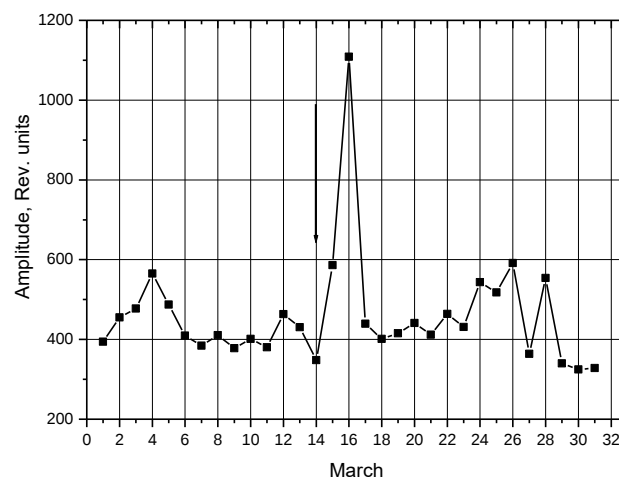


Figure 1. Variations of average amplitude of atmospherics passing over the epicenter of the earthquake in Japan on 14.03.12.

The day of the earthquake in Figure 1 marked by a vertical arrow. As follows from the figure, the effect of the lithospheric perturbations manifested in the amplitude of atmospherics two days after the event, namely 16.03.12 observed well-defined peak amplitude exceeded of the background signal level almost for 3 times. Ten days before the event (04.03.12) there was an increase of the amplitude of about 1.5 times, which in this case can be considered as a precursor of the earthquake. One of these events (the second considered here lithospheric perturbation) took place in Indonesia with epicenter coordinates 1.788° N; 127.318° E, 07.01.09. Magnitude was 5, and focal depth (96 km) is almost twice the commonly used threshold.

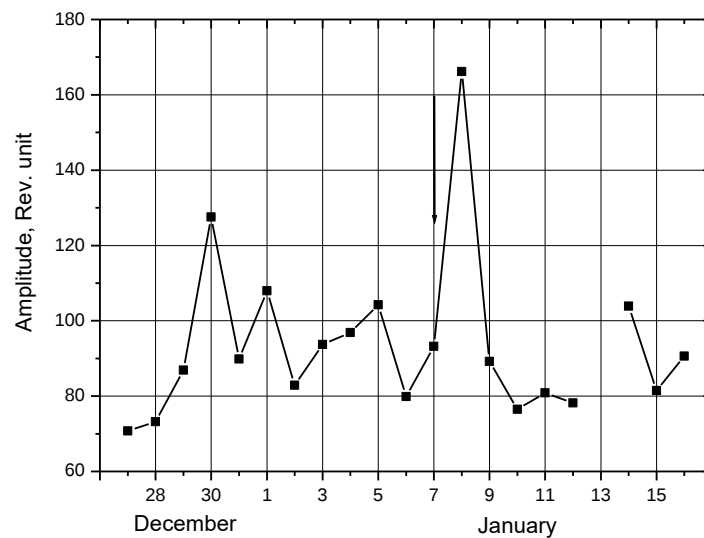


Figure 2. Variations of average amplitude of atmospherics, passing over the epicenter of the earthquake in Indonesia on 07.01.09.

Variation of the mean amplitude of the night atmospherics (00-01 LT) in this event are shown in Figure 2. Comparing with the above considering event 14.03.12, it may be noted that the effect of the earthquake followed the next day after the event, there is also well expressed - the peak of amplitude of nearly for 2 times above the level of amplitude in the previous week interval before the earthquake. The sharp increase in the amplitude of atmospherics observed 30.12.09, also almost 2 times higher the level in the preceding days, can be seen as a precursor of the earthquake.

The third earthquake occurred on Lake Baikal on August 27, 2008. The chamber depth was 10 km, and the magnitude was 6.3. This earthquake is of interest because it occurred at the divergence of tectonic plates and it was interesting whether the effect or the precursor would manifest itself in the ionospheric parameters. Figure 3 shows variations in the signal amplitude from the direction to the earthquake. The missing days on the graph of amplitude variations are associated with low thunderstorm activity behind the epicenter of the earthquake. But despite this, amplitude variations were recorded, most likely associated with the lithospheric disturbance at Lake Baikal.

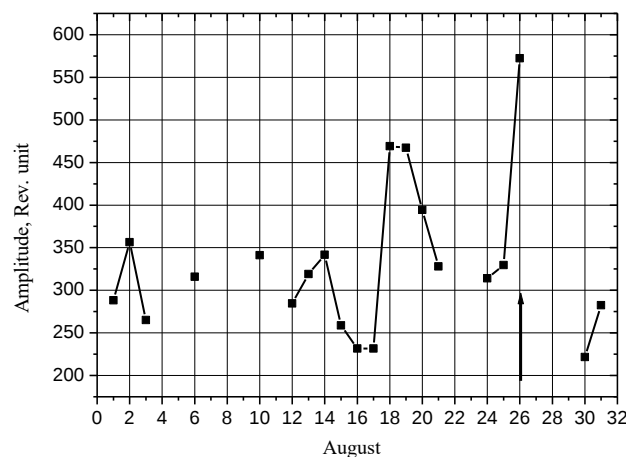


Figure 3. Variations of average amplitude of atmospherics, passing over the epicenter of the earthquake in Baikal on 27.08.08.

As can be seen from the graph of variations in the amplitude of electromagnetic signals from lightning discharges propagating over a given earthquake, there is a sharp increase in the amplitude on the day of the earthquake, which we associate with its effect. We associate the increase in amplitude on August 18 and 19 with its possible precursor. Thus, it can be assumed that earthquakes that occur at the divergence of tectonic plates can have ionospheric effects

At present, there are several main theories describing mechanisms of effects of seismic disturbances on the lower ionosphere. The occurrence of inhomogeneities in the ionosphere over earthquake epicenters is associated with Joule heating that occurs during the development of the auroral electrojet during the period of magnetospheric substorms. [6]. In [7], the authors proposed a theory that an infrasound connection between lithospheric and ionospheric disturbances can occur at the moments of earthquakes and during their preparation.

The most common theory is related to the dissipation of AGW, which is presented in [8]. It describes quite completely the physical processes in the ionosphere that can be caused by AGW. When propagating upwards, the AGW will dissipate at altitudes of 80-100 km, which is expected to result in the increased turbulence and increase of the temperature of neutral particles that affecting the propagation conditions of electromagnetic signals in the Earth-ionosphere waveguide.

Another possible mechanism presented in [9], which describes a model of influence of lithospheric processes on the ionosphere. It is associated with atmospheric or electromagnetic processes, is widely considered.

4. Conclusion

Results of the analysis it is established that disturbances in the lower ionosphere caused by lithospheric processes, can be manifested in the variations of amplitude of the thunderstorm signals propagated over earthquake epicenters. The amplification of signal amplitude taking place some days before the events can be considered as a precursor. It allows to use observations of impulse electromagnetic thunderstorm signals as one of possible means of distant monitoring of strong earthquakes.

5. References

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