SOME IONOSPHERIC RESPONSES TO EARTHQUAKES

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Since 2010 long term observations by ionosonde in Kazan with 1-min intervals is made. Such operating mode allows rare effects occurring in ionosphere and caused by earthquakes and big explosions would be record in ionogram. In paper the characteristic features (signature) of severe events are detected in ionograms when the epicenter was at a great distance. The revealed signatures are a F1 layering, appearance of a trace focusing and a particular TID in ionograms. The duration of these events is defined and calculations of speed of wave disturbances is made.

Introduction

All of the processes taking place under ground, on the ground and in the air are coupling. The ionosphere is the unique place, on the one hand, where are many different wave disturbances converging, the acoustic and internal gravity (AGW), and on the other hand, the radiowaves path have a significant influence when radiowaves cross regions effected by AGW. Such effects on the parameters of radiowave propagation is often observed by applying a rapid vertical sounding, consequenty the important problem is accurately identify sources of disturbances which observed in the ionosphere.

Important in terms of saving lives is the identification of earthquakes including their predictions, and their detection. Predictions are more complex problem, and in this paper we do not consider. In work we paid attention to the response from the earthquake and from big explosions. Large number of disturbances at one day was observed in the ionosphere. A terminator and internal gravity waves (IGW) generated by jet streams and disturbances in the polar cap are considered as universally recognized source of wave disturbances, but it is not enough to explain the all observed disturbances on ionograms. The usual form of disturbances on ionograms is TIDs (in form of a cusp and a focusing). Because of their frequent appearance to select those TID related with earthquakes is difficult.

The way when ionograms recorded near the epicenter of the earthquake is more productive, and then characteristic response of the ionosphere are allocated. Clearly, in this case, for greater reliability, and in order not to miss impact, the ionosonde must operate at a intervals less than a minute. This estimate was made from our observations of the short lifetime of the TID (~ 5 min).

First ionospheric response has been studied for an earthquake in Alaska (28 March 1964) [Davies, Baker, 1965; Leonard, Barnes, 1965]. Vertical ionospheric sounding stations were located close to the epicenter. At all stations are properly registered disturbances in F-region, it was significant and long-lasting increase in the electron density and the occurrence of wavy damped oscillations of the plasma density. Disturbances amplitude depended on the distance between the sounding station and the epicenter of the earthquake. So, on the nearest ionosonde to the epicenter of the earthquake disturbance apparent in the form of anomalous ionospheric F-scatter, lasting at least 10 minutes.

At present time, this type of F-scatter associated with passing overhead the large-scale irregularities of the electron density plasma with sharp boundaries [Bowman, 1990]. On remote ionosondes the disturbance apparent in the form of the anomalous increase of the F-layer critical frequency, which was preceded its falling.

Usually earthquakes was observed in Doppler experiments, which allows continuous receiving of signals without gaps with high sensitivity [Gohberg, 2008]. But the complexity of

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data interpreting at a fixed frequency does not allow to recover a frequency-spatial pattern of disturbance. Due to the fact that the earthquake is an unexpected phenomenon, there is no clear typical responses on ionograms from earthquake.

The most interesting event from a scientific point of view was Tohoku earthquake of March 11, 2011, when its magnitude excess of 9. And most importantly, that the five ionosondes worked was not far, one of whom operated with 5 minutes interval, and four other operated with 15 minute. A response from the earthquake is displayed the five typical ionograms showing multiple layering of F1-layer [Jann-Yenq Liu et al., 2011, Maruyama et al., 2011].

It is interesting that all five ionosonde showed the same type of response to the earthquake, unfortunately four ionosonde worked in 15 minutes mode, and duration of response has not been established. This earthquake was the source of the reference response to the earthquake, which is to be found in other earthquakes. In our investigations were chosen earthquakes magnitude greater than 8 (on the website http://earthquake.usgs.gov).

Results

So the Sumatra island in April 11, 2012 at 08:38:38 (UTC) (14:23:09 - Kazan), there was an earthquake of magnitude 8.6 balls at a distance of 10,576 km to Kazan. Near 49 minutes after the event on the ionogram in Kazan was observed F1-layering, hence, the speed of the perturbation is ~ 12,000 km / h (3,500 m / s). Is considered that Rayleigh wave has such a high speed of propagation, and generates TID which called as STID [Jann-Yenq Liu et al., 2011, Maruyama et al., 2011]. To better define the propagation channels need to use data from seismograph. This disturbance was extended about 10 minutes. In Fig. 1 on each panel in the ionogram are enlarged fragments of the stratifications of F1-layer. This phenomenon is rarely observed by ionograms and can be used as an occurred earthquake signature with magnitude excess over 8.

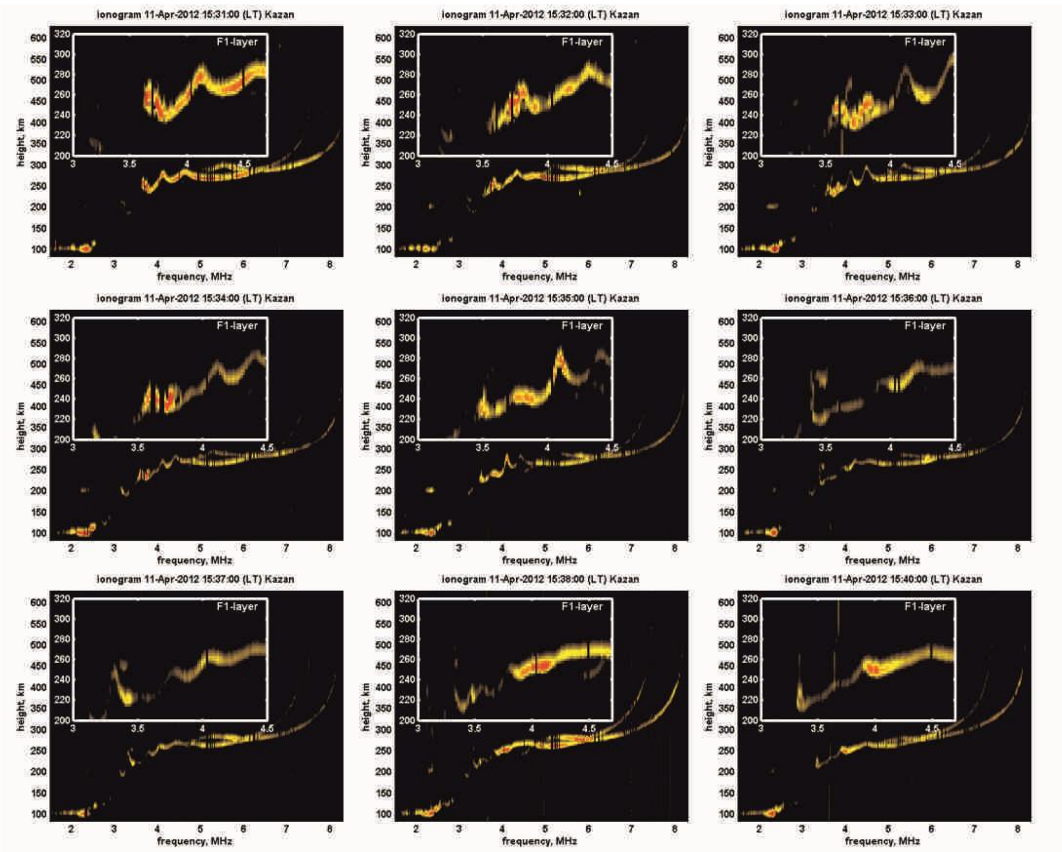

Fig. 1. Example of a sequence of ionograms showing F1-layer layering. After the earthquake in Sumatra, April 11, 2012 at 08:38:38 (UTC) (14:23:09 - Kazan).

The following Fig. 2 shows another type of response to the earthquake in Santa Cruz Islands February 06, 2013 at 01:12:23 (UTC). The phenomenon of focusing the reflected signal from F-layer observed in Kazan ~ 03:20 UTC (~ 7:20 LT) or 2 hours 10 minutes after the event. Distance from Kazan to Santa Cruz Islands is ~ 14000km, so the speed is ~ 6500 km/h (1,800 m/s). Arrows show areas with increased amplitude in the scattering F-trace.

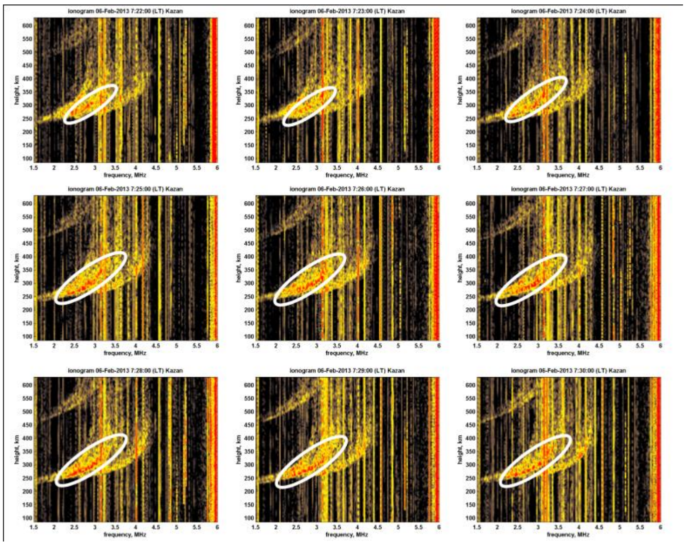

Fig. 2. Example of a sequence of ionograms showing the response to the earthquake Santa Cruz Islands February 06, 2013 at 01:12:23 UTC (response in Kazan at 03:20 UTC) in the form of focusing the scattered F-layer (circles).

Below in Fig. 3 shows the sequence of ionograms, where the TID after the invasion the Chebarkulsk (Chelyabinsk) meteorite. Distance from Kazan to Chebarkul is ~ 700 km (~ 800 Chelyabinsk). Phenomenon focus on ionogram Kazan seen in ~ 4:35 LT (meteorite fall - ~ 3:20 UTC). This allows us to calculate the approximate speed of propagation of a shock wave at 200 m / s (~ 700 km / h).

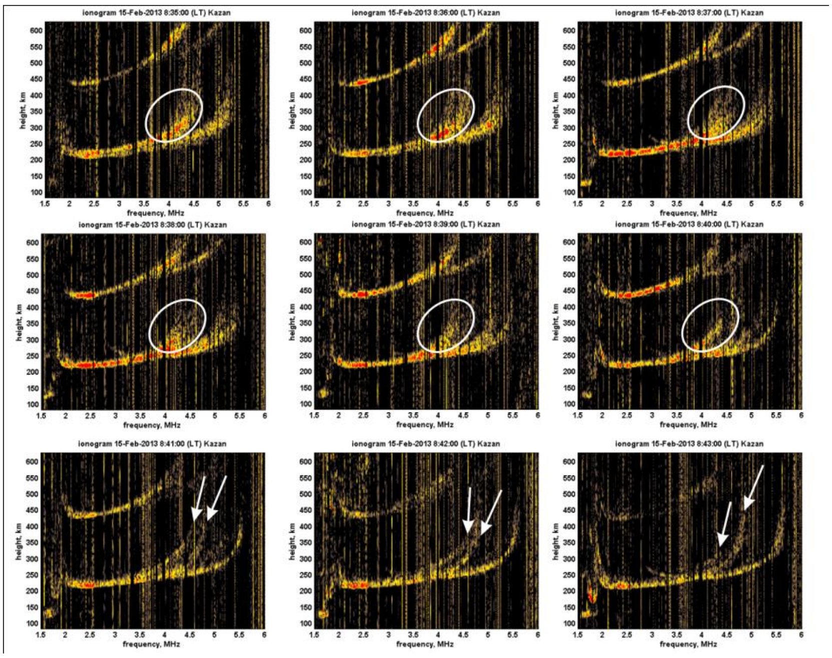

Fig. 3. Sequence ionograms during the Chebarkulsky (Chelyabinsk) meteorite invasion. in the early ionograms the F-scattering noted by the circles. The TID traveling in the last ionograms marked by arrows.

Conclusions

One minute mode ionogram registration allowed to observe the ionogram signatures from earthquakes with a magnitude greater than 8 at a large distance from the epicenter. The main response (signature) is the F1-layer layering. At night time, the identification is more difficult then F1 is absent and F-spread is often present. In such conditions we observed the focusing (increasing in amplitude) of some area of the F-spread. These phenomena have a short duration of about 10 minutes (or less).

Explosive phenomena generated by the invasion of meteorites, which are visible on ionograms as an extra trace, coming down to the main. The period of time between the explosion and the registration on the ionograms shows acoustic channel of propagation (in the form of a shock wave).

One minute mode ionograms registration allows to record rare phenomena in the ionosphere, in particular allows us to monitor earthquakes or other explosive events. In the case when we know the exact time and place of the severe events we can roughly estimate the speed of the waves, and thus the propagation channels of the disturbances.

Earthquakes of magnitude less than 8 don't have a response in the form of F1-layering, and to identify response need to additional work.

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