# Ionosphere disturbance during cosmodrome "Vostochniy" launches

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**Abstract.** It is known that during spacecraft launches ionospheric plasma properties are modified in the result of impact of shock-acoustic waves generated during carrier rocket supersonic motion. As a rule, investigation of ionospheric plasma variations is carried out by the signals of Global Navigation Satellite Systems GPS/GLONASS that implies ground station network. There is no such a system near the "Vostochniy" cosmodrome that makes it necessary to search for an alternative solution. One of them may be the application of ionosphere vertical and oblique sounding stations. Based on the analysis of such station data, the possibility of evaluation of ionosphere modification during "Vostochniy" cosmodrome launches is shown.

When the "Vostochniy" cosmodrome was put into service, we got the opportunity to investigate the ionosphere reaction on spacecraft launches in the Far East. Based on the analysis of signals of the Global Navigation Satellite System GPS/GLONASS, ionosphere disturbances caused by the first carrier rocket (CR) from the new cosmodrome on April 28, 2016 were detected in the paper [1]. However, if we turn to the site [2], which show the location information on GNSS stations included into IGS International Network (International GNSS Service) and located near "Vostochniy" cosmodrome, their number is not enough for full observations (Figure 1).

It is clear from the figure that there are just few stations in the Far East that is in contrast to the number of stations in Japan. Obviously, in such a case we should use other methods to investigate the effects during the launches, for example, ionosphere vertical and oblique sounding station of IKIR FEB RAS and Rosgigromed IPG, located in Khabarovsk, Magadan and Paratunka (Kamchatka).

CR "Souz-2.1b" with upper-stage rocket "Fregat" and SC "Meteor" was launched from "Vostochniy" cosmodrome at 05:41:46UT on November 28, 2017. The trajectory was oriented northward. Observation complex including ionosphere intensive vertical sounding by digital ionosonde "Parus" (Paratunka) and station SP-2 (Khabarovsk) was carried out at IKIR FEB RAS Geophysical Observatories. Standard operating procedure of the ionosondes assumes the measurement with the period of 15 minutes but several hours before the launching, the stations were switched over to 5-minute mode of sounding. Based on the CR flight sequence, velocity corridor of shock-acoustic wave propagation [3] and the distance to observation sites (about 2000 km to Paratunka and 680 km to Khabarovsk observatories), we

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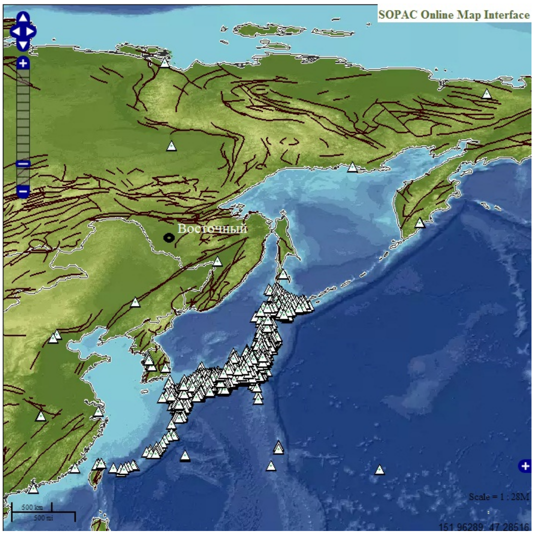


**Figure 1.** GNSS station location in the Far East [2]

determined the probable time of disturbance arrival to Khabarovsk and Paratunka. Then we analyzed the ionograms in the obtained time intervals in Khabarovsk, Figure 2.

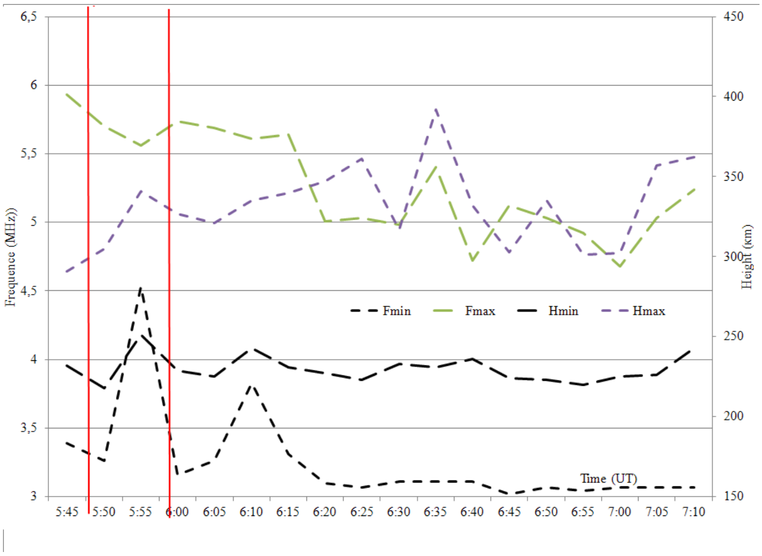


**Figure 2.** Analyse ionograms of "Khabarovsk" station

During the launching, the Earth magnetic field was slightly disturbed. Dst was -(10-16) nT, and Kp 2+ [4]. Consequently, natural disturbances of electron concentration were unlikely [5]. It is clear from Figure 2 that the are no reflections at the frequencies of 3.33-4.13 MHz and the virtual heights of 223-268 km on the ionograms of "Khabarovsk" station at 05:55UT. Slight change of track inclination is observed on "Paratunka" station ionograms at 06:15UT. The latest ionograms were processed and the tracks are illustrated in Figure 3. Thus, we can make a conclusion on electron concentration gradient change.

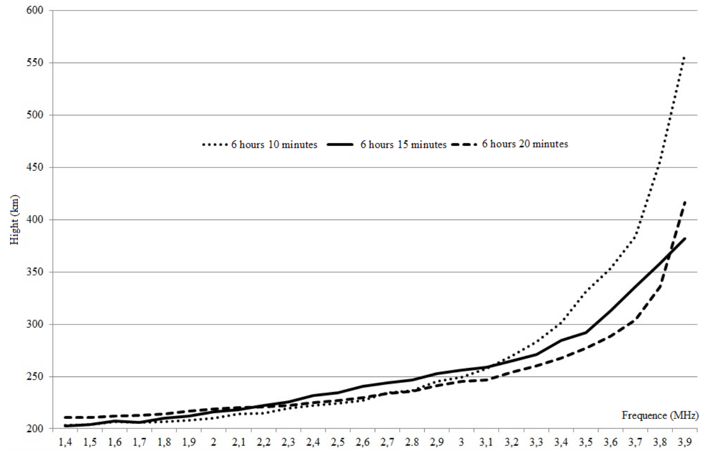


**Figure 3.** Results of ionogram processing ("Paratunka" station).

An attempt was made to apply the data of an oblique sounding station "Khabarovsk-Tory" (Irkutsk) [6]. There are anomalies in the remote-frequency features of oblique sounding stations which are characteristic for a moving ionospheric disturbance, Figure 4.

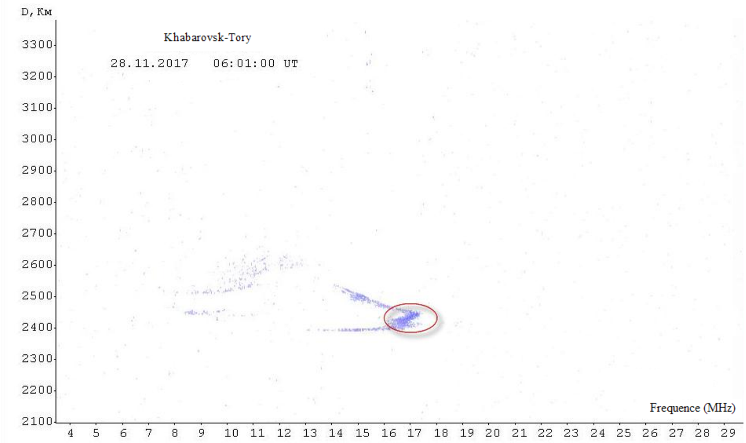


**Figure 4.** Remote-frequency characteristics of oblique sounding station

The next launch from "Vostochniy" cosmodrome took place on February 01, 2018. During this event, ionosphere disturbance was not recorded at the stations mentioned above. However, it was observed at Mohe station in the North of China, Figure 5. It is clear from the figure that the disturbance has a form characteristic for moving ionospheric disturbances.

The instability of detection is likely to be determined by the following circumstance. The shock-acoustic wave velocity is about 1 km/s. The ionosonde visibility zone is about 100 km. Then the time of wave passage across the visibility zone of the ionosonde was ~1.5 minute.

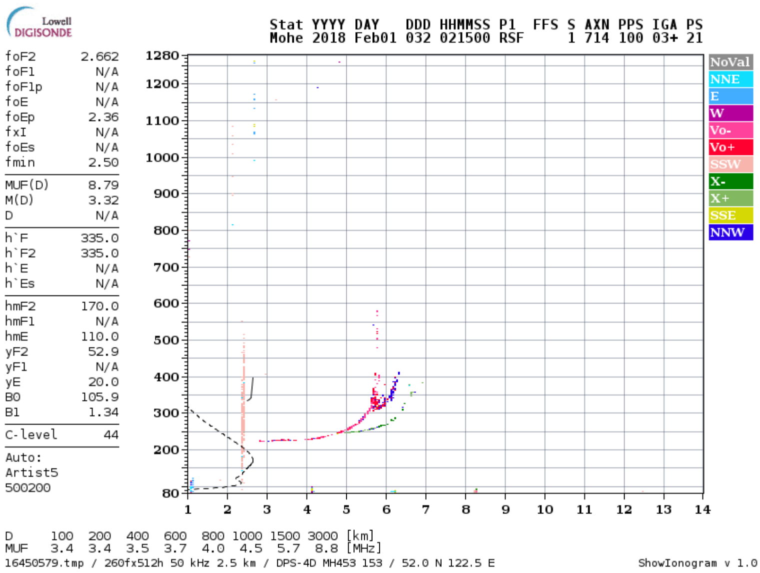


**Figure 5.** Ionogram of Mohe station

The measurements were made with the interval of 5 minutes that is three times as much as the time of the disturbance passage across the ionosonde visibility zone. As long as the measurement sampling is more than the time of wave passage, the probability of successful measurements is not high.

We should note that the observations are occasional and the ionospheric stations are located non-optimally in relation to CR flight boost phase. It does not allow us to make reliable conclusions, but we can assume that the absence of the track part is associated with anomalous absorption likely to be caused by the collision number increase or electron concentration gradient change.

## Conclusions

1. The observed ionospheric disturbances are likely to be caused by CR launches from "Vostochniy" cosmodrome.

2. To investigate the ionospheric disturbances caused by "Vostochniy" cosmodrome launches, vertical and oblique sounding stations, located in the Far East, may be applied.

3. To increase the time resolution, sounding intervals should be decreased.

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