Meteor induced layers in 2013 observed by ionosonde with high cadence

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Introduction

It is considered that the main theory explaining appearance of sporadic E is the theory of wind shear, which means (includes) the presence and movement of nodes converging tidal wind through the height region of the most frequent occurrence Es (120-140km) [Mathew et. all, 1998]. However, the appearance of intense layers, following its name, are sporadic, and such variability cannot to explain by the influence of tidal waves only. Another indication inconsistency theory of wind shear is the appearance of so-called transient Es layers [Maruiama, 2003]. The distinctive feature of this trace is the high critical frequency (> 5 MHz), a constant height, weak amplitude, all trace semitransparent and short lifetime [Maruiama et. all, 2003 and 2008 and references there], see for example Fig. 1. Because of duration, such layer is opposite to the traditional persistent Es layer, which we do not consider in this paper. Various researchers have used different terms for such spontaneous Es, it is meteor echo, meteor induced Es, spontaneously formed sporadic Es patches resulting of the Fresnel scattering from a region of enhanced plasma density along the meteor trail, transistory Es and transient Es. Since the term transient Es is unstable, to avoid confusion, we will stick to this term. Since meteor echo is not fully satisfy this term by some parameter, we will describe the properties of transient Es based on the ionogram properties and not from physics of its origin.

Investigation of transient Es performed by Japanese scientists when ionosonde worked in one-minute mode during major meteor showers. The distinctive feature of the presented results is the high quantity of transient Es or meteor echoes with the average value in ~2000 per 102 hours [Maruiama et. all, 2003]. Part of traces they associate with meteors when foEs> 8MHz. But apart from them were observed transient Es with low-frequency 5MHz <foEs <8MHz., which are not directly been associated with meteor showers and do not correlate between adjacent ionosonde, because of what they are called spontaneous Es. All this points to the fact that part of the transient Es comes from meteor showers, while others are associated with non-showers sporadic Es or with a delay after the occurrence of the meteor events due to the increased presence of metallic ions or even something else.

To verify the conclusions of Japanese researchers in the region of Eastern Europe (Kazan), we used data from our ionosonde with one-minute rate ionograms registration. For processing performed a method are using to select beatings and the ionosphere reflectivity of the layers by means A-, H-and A_Σ-map [Akchurin, 2011; Yusupov, 2014].

Experimental methods and equipment

To study the transient phenomena in the ionosphere from February 2010 measurements near Kazan are performed using ionosonde "Cyclone" in 1 minute mode. Therefore the opportunity studying of the transient Es statistics appear.

From a processing perspective our transient Es-trace reminds Es-trace of type f (flat), not having cusps or at the beginning or at the end. In most cases, it appears below the E-layer about 100 km, and therefore it can be referred to the type of l (low). Distinctive features of transient Es-

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layer is the small amplitude of the echo and short lifetime. Given the similarities of stable Es with transient Es-layers means that the specified technique for allocating Es-layers can changed.

To improve the reliability of this research the searching was in several stages of testing using all information provided by the A-, H-and A_Σ-maps (see Fig. 2), without viewing the entire stream of ionograms. Given that the researched by us trace reminds persistent Es layer, it does not require significant processing of A-maps for accounting transient Es. Because the transient Es has a short lifetime and a weak amplitude, it is not always be seen at such maps. Work with only one map can cause the skip Es-trace, and only working with three maps can reduce mistake to a minimum. Additionally, to reduce mistakes A-and AΣ-maps were marked contrast, which greatly facilitates efforts.

In the first stage of processing the simultaneously A-, H-and AΣ- maps plotted. At the second stage the circles marked at A-, H-maps, showed signs of transient Es (at the limiting frequency). Third at the A_Σ-map such Es appears like concentrated dark dot, which is a sign of its height location. For transient Es, to illustrate, the some typical points are marked with the dashed arrow at all three maps in Fig. 2 (paper sizes do not display the transient Es variations in detail so in this paper the result shown for half a day).

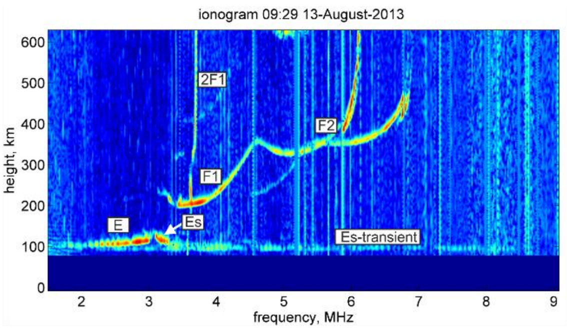

Fig.1.

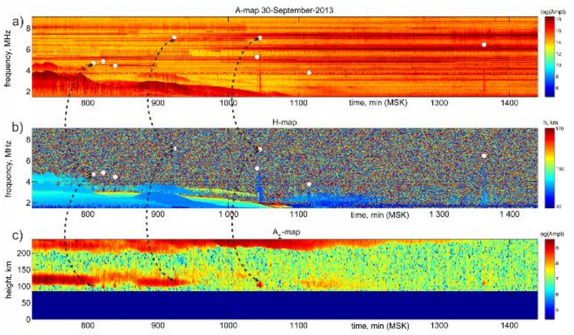

Fig.2.

Fig.1. Example of ionogram with marking regular layers of the ionosphere and transient Es.
Fig.2. Example of interactive processing for transient Es allocation: a) A-map, b) H-map, c) A_Σ-map. Circles marks transient Es and/or their critical frequencies. To illustrate, the arrows mark some signs of transient Es identical in all maps.

Data analysis

The distinctive feature of Japanese researchers is not a high number of occurrences and the lack of a large critical frequency. Because our statistics are less, we have not studied the daily variations in specific day, and studied the variation with monthly and annual averaging (see Figure 3). The first step in the analysis was a comparison of occurrence statistics of transient Es throughout the year with the meteor showers appearance. The above analysis showed that the appearance of the peaks clearly correspond to activity maxima dates of major meteor showers. However, in addition to emissions there is a sufficiently large constant background having a seasonal dependence, which may associate with meteor showers. At the same time, we note that there is little seasonal dependence. What could possibly due to the fact that the showers in the northern hemisphere are more frequent in the second half of the year than in the first.

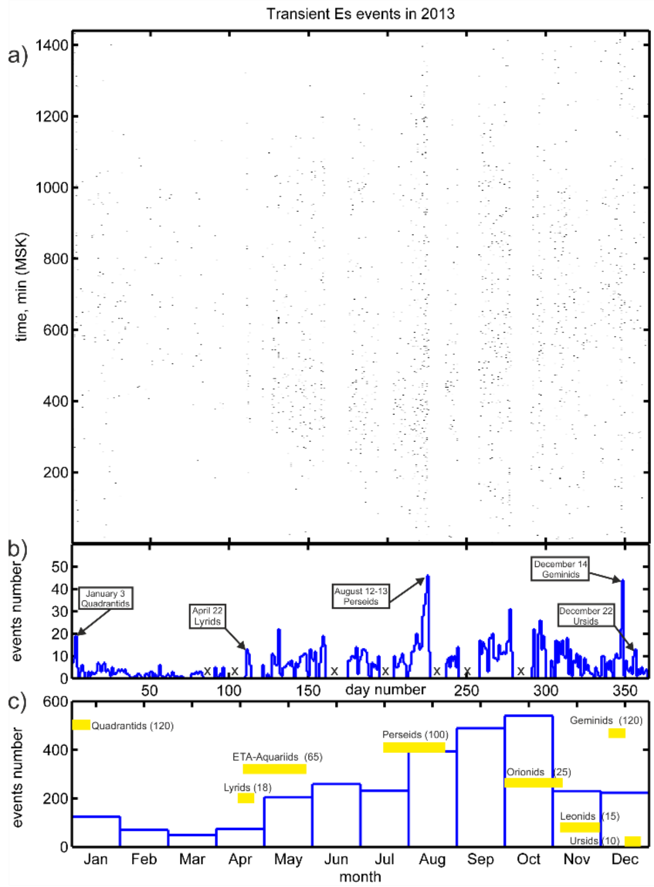

Fig.3. Plot of transient Es full appearance for 2013: a) in the coordinates day of the year - minutes a day (black dots in a white background); b) the average number of occurrences within a day (x notes non-working ionosonde periods); c) the average number of occurrences within a month, and yellow rectangles marked approximately main activity periods of meteor showers in the southern hemisphere (information about meteor showers taken from http://www.imo.net).

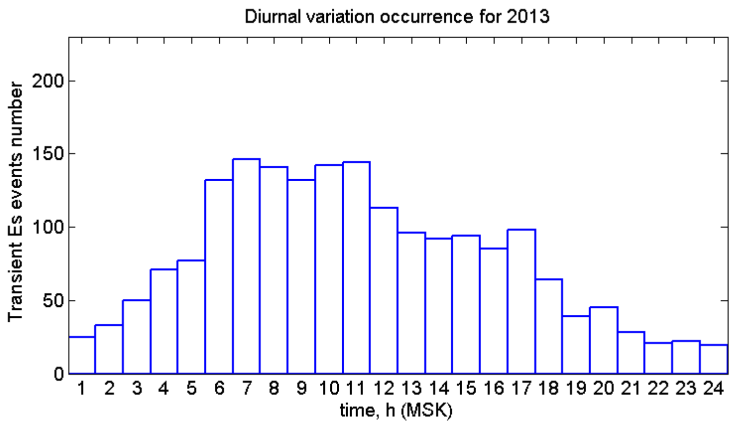

Fig.4. Diurnal variation of transient Es occurrence averaged over 2013.

In this way, for the entire year we found statistics which is about as much as in Japan for 102 hours. And to determine the physical processes influencing the formation of transient layers was also discussed daily variations of appearance, with an annual average (see Fig. 4). As mentioned above, our statistics is much smaller than the Japanese so we consider a histogram of the diurnal variations for the entire year. Which indicates the presence of a maximum from 5 to 11 h in the morning, which could be caused by meteors. However, in the afternoon transient Es also observed. The peak morning explains the relationship with meteor showers, and the presence of activity in the other clock indicates the presence of another mechanism leading to the appearance of these layers, which requires further investigation.

Conclusions

One-minute measurements in 2013 allowed revealing the events number of transient Es. Analysis of the frequency of occurrence led to the following conclusions:

1) The appearance has seasonal and diurnal dependence. It observed, the diurnal dependence has the increase in the morning hours, and seasonal dependence has a maximum in the end of summer and autumn, and a minimum in the end of winter and in the beginning of spring.

2) In the plot of the seasonal dependence are sharp peaks in January 3, April 22, August 12-13, December 14 and December 22, coinciding with the periods of maximum occurrence of strong meteor showers Quadrantids, Lyrids, Perseids, Geminids and Ursids.

3) Such peaks in seasonal and diurnal dependencies indicates that a significant part of transient Es caused by frequently appearance of meteors (of meteor showers). That are favorable factor to contribute the appearance of transient Es.

These results show that meteors separately and wind shear theory does not explain the occurrence of transient Es traces. If the seasonal dependence coincided exactly with the maxima of meteor showers, that the diurnal dependence has 1-2 hours difference. Furthermore transient Es appear in the second half of the day, when the meteor showers are not present. For the theory of wind shear, the inconsistency is random appearance and short lifetime.

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