A statistical study of medium-scale ionospheric disturbances generated by solar terminator registered over Japan in 2008

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Abstract

A statistical study of wave packets of terminator origin using GEONET GPS data for 87 days in 2008 was done. There were some seasonal and latitudinal features in occurrence of the packets. In spring packets are registered 1.7 times more often in the south region than in the north one and in summer – 1.3 times more often in the north than south region. Autumn packets registration rate have two maxima: 4 hour after and at the same time as terminator appears over the registration point. Similar distribution maxima are registered in summer in the south of Japan.

1. Introduction

In spite of many investigations of the solar terminator atmospheric effects [1] there were no reliable evidences of generation of medium-scale ionospheric disturbances while the terminator propagates up to recent time. The GPS technology allows making considerable progress in this field. This technology allows getting data of total electron content (TEC) variations with high spatial-temporal resolution. The methods and technology GLOBDET of global GPS detection of ionospheric disturbances were developed in ISTP SB RAS [2]. The GLOBDET permits to investigate ionospheric disturbances with amplitude up to 10^{-3} of the diurnal TEC variation.

For the first time in the paper [3] the existence evidence of wave structure generated by the solar terminator (ST) propagated above USA, Europe and Japan was obtained. It was found that medium-scale wave disturbances generated by the solar terminator manifest themselves as traveling wave packets (TWP). In the later papers the spatial-temporal features of TWPs were analyzed and general TWP morphology under different levels of the geomagnetic activity for a long time period (1998-2007) was presented [4]. At the same time some essential questions are still unclear – for example, on peculiarities of the TWP morphology depending on season and geographic location of registration point.

In this paper we analyze statistics of TWP parameters in solar activity minimum. To analyze features of generation of the wave packets while the solar terminator propagates we consider statistics of TWP parameters for two regions of Japan. We used data of TEC measurements in the RINEX format from the Japanese dense net of GPS receivers GEONET (ftp://terras.gsi.go.jp/data/GPS_products/).

2. Data processing

The standard GPS technology provides a means for wave disturbances detection based on phase measurements of TEC I(t) along line-of-sight "receiver-satellite GPS" [5]. We obtained TEC variations dI(t) by moving average filtering from the initial I(t)-series over the range of periods of 5-20 min.

The technology for global detection of TWPs that was developed at the ISTP SD RAS makes it possible to select – from a large amount of experimental material in the automatic mode – the TEC disturbances which can be assigned to a class of TWPs [6]. The selection of TEC series which could be ascribed to a class of TWPs was carried out by two criteria. First of all, TEC variations were selected, for which the value of the rms exceeded a given threshold ε (in the present case ε = 0.05 TECU). In addition, for each filtered series, we verified the fulfillment of the "quasi-monochromaticity" condition of TEC oscillations, for which the ratio R of a sum of spectral amplitude in the selected frequency band δF in the neighborhood of a maximum value of the amplitude S_{max}, to a sum of spectral amplitude outside the frequency band δF under consideration exceeded a given threshold R_{min} (in the present case $R_{min} = 2$).

We analyzed following characteristics of the TWPs: maximal amplitude A, time period T, duration ΔT (determined as duration of the packet envelope by level A/2), time of maximum amplitude registration t_{max}. The analysis was done for TWPs registered during 87 days in 2008 (spring – 18 days, summer – 41 days, autumn – 28 days) using data from Japanese net of GPS receivers GEONET. For analysis of latitudinal features to be performed two regions were chosen – (30-35^{0}N; 130-140^{0}E) and (38-45^{0}N; 138-145^{0}E). For easy reference we

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call these regions as south and north regions, respectively. Number of GPS sites in south region is ~460 and in north region – about 280.

Connection between wave packets generation and ST appearing presents most obvious in the terminator local time (TLT) system: $dT = t_{max} - t_{st}$, where t_{max} is the instant of WP maximum registration in current point, and t_{st} is the time of ST appearing at the altitude h=300km over this point [4]. Distinctive feature of this approach is in excluding of the point coordinates and considering data of each point in the solar terminator context only.

3. Results

Table 1 presents average amount of TWPs: $\langle N \rangle = N_{pack}/(N_{days}*N_{sites})$, where N_{pack} is a registered TWPs amount, N_{days} is a number of registration days and N_{sites} is an amount of sites in current region. Thereby, value $\langle N \rangle$ characterized an average TWPs amount at single site per twenty four hours.

Table 1. Average amount $\langle N \rangle$ of registered TWPs in two regions of Japan for different seasons

	Spring	Summer	Autumn	Full year
South region	3.1	3.6	1.3	2.8
North region	1.8	4.7	1.2	3

The table shows that for the full year in both regions about 3 packets were registered at an average for each site at 24 h (last column). Seasonal variations of both south and north region TWPs amount are quite similar: maximal value is observed at summer and minimal – at autumn. However, there are several differences. Spring TWPs amount in the south region is about 1.7 times greater than in the north region and for summer this amount is 1.3 times lower.

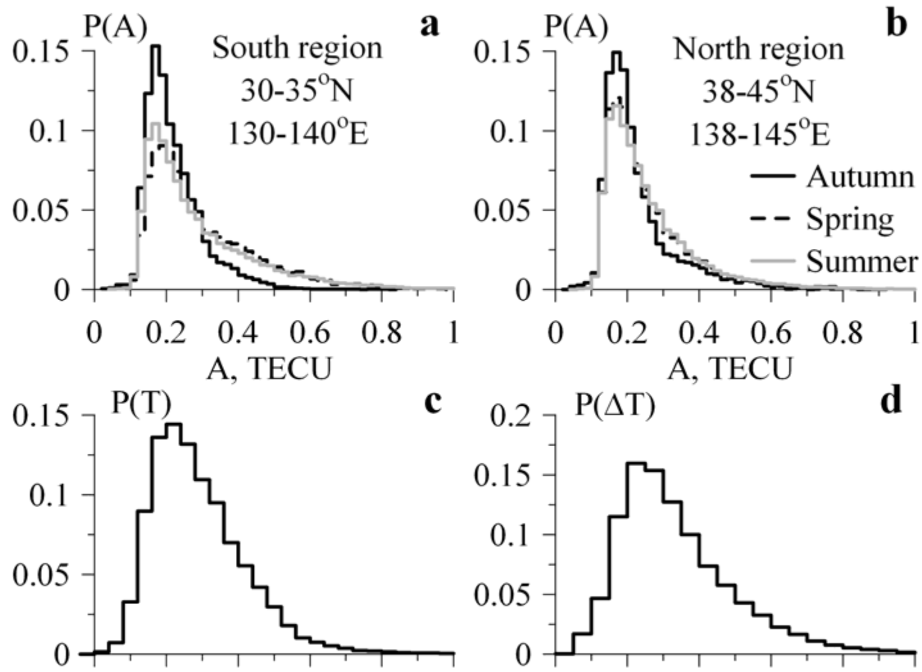

Fig. 1. Distributions of following TWP parameters: amplitude P(A) for South (a) and North (b) regions; period P(T) (c) and duration P(ΔT) (d). For panels a, b: solid black line corresponds to autumn, dashed line – spring, gray line – summer.

Figure 1 presents distribution of amplitudes P(A) for south (a) and north (b) regions, periods P(T) (c) and durations P(ΔT) (d) of TWPs. Analysis shows distributions P(T) and P(ΔT) are almost the same in both regions and practically independent on season. Most probable values of period T and packet duration ΔT are about 20 min and about 0.4 – 0.5 hour, respectively. Half-widths of those distributions are 15 min and 0.6 hour. Pronounced seasonal variations are observed for amplitude distribution P(A) only. Most probable amplitude value is practically stable (~ 0.16 TECU), but distribution form is changing. Spring and summer amplitude distributions P(A) are wider than autumn one in both regions, but in the south region this phenomenon more expressive: autumn distribution half-width is about 0.1 TECU, whereas spring and summer ones are about 0.14-0.16 TECU (fig. 1a). In the north region autumn half-width of the last distributions are about 0.12 TECU.

In the figure 2 relative TWPs amount distributions in terminator local time system P(TLT) are given. In both regions in summer (gray lines) TWPs appears about 2-3 h before ST appearance over the observation point. Summer maximal TWPs amount in north region is observed about one hour before ST appearance and in south region it concurs with ST appearance. Summer distribution P(TLT) in south region have second maximum about 3 hours after ST passage. North region spring distribution maximizes about half an hour after ST passage and in south region the distribution has maximum about an hour after ST. Autumn distribution P(TLT) in both regions have two maxima (marked by circles) with 4 hours interval between them. In the south region they are registered about 1 hour earlier than in the north one. In the north region first maximum bigger than second one and it is inversely in the south region.

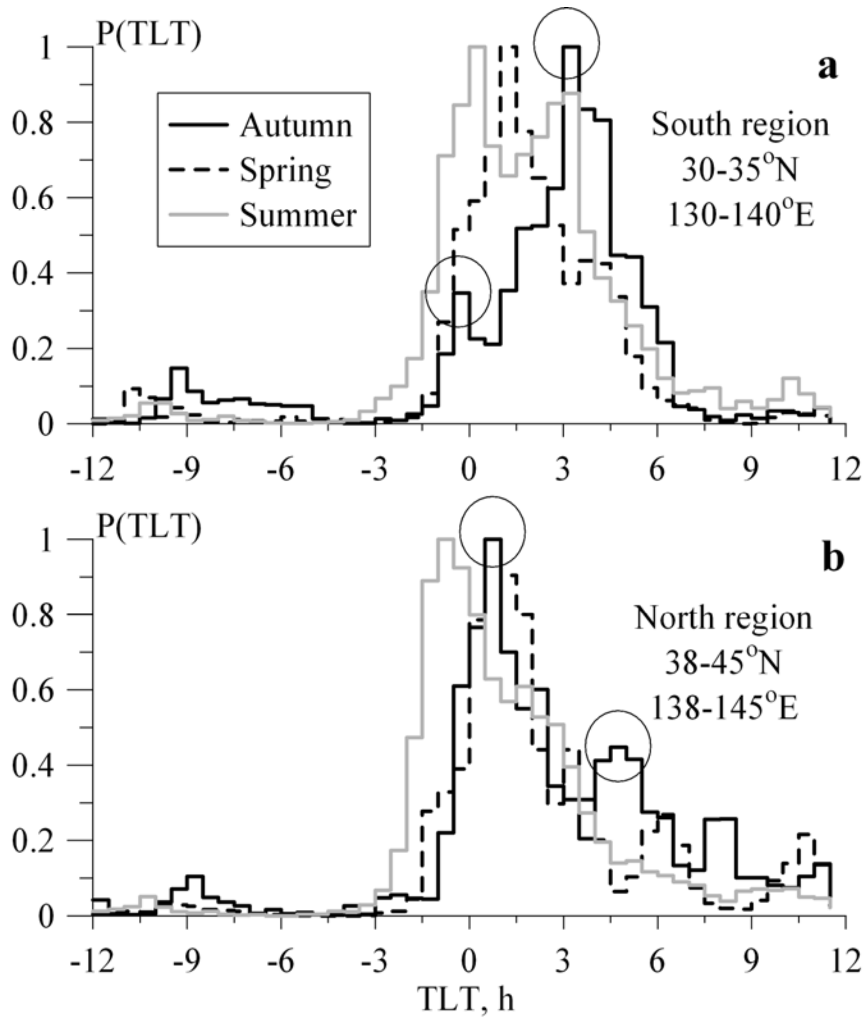

Fig. 2. Distributions of TWP depending on local time of evening ST. Distributions for different seasons are marked in the same way as in Fig. 1.

4. Conclusion

There was found several distinctions in TWPs registration over Japan:

1) In spring wave packets are registered 1.7 times more often in the south region than in the north one and in summer – 1.3 times more often in the north than south region.

2) Derived distributions of amplitude, period and duration time of wave packets are in qualitative and quantitative agreement with previous results [7]. Spring and summer distributions are 1.2-1.6 time wider than autumn one.

3) Autumn TWPs registration rate have two maxima: 4 hour after and at the same time as ST appears over the registration point. In the south of Japan those maxima appears 1 hour earlier than in the north. Similar distribution maxima are registered in summer in the south of Japan and time interval between them is about 3 hours. Summer registration maxima are probably connected with generation of TWP by ST in two areas: local and magneto-conjugate regions. Autumn distribution maxima formation mechanism is still unclear.

Our results points to necessity of further investigations of wave packets characteristics in dependence on season, region, geomagnetic activity level etc.

5. Acknowledgments

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