"Physics of Auroral Phenomena", Proc. XXXIX Annual Seminar, Apatity, pp. 97-100, 2016
© Polar Geophysical Institute, 2016

Polar
Geophysical
Institute

DAYTIME N_mF2 ANOMALOUS DEPENDENCE FROM SOLAR ACTIVITY IN THE MIDDLE AND SUBAURORAL LATITUDES IN JANUARY 2012–2015

M. Klimenko[1], N. Korenkova[1], V. Leshchenko[1], A. Markov[2], A. Abdullaev[2], K.G. Ratovsky[3], A. Vesnin[3]

[1]*West Department of Pushkov IZMIRAN RAS, 41, Pobedy Av., Kaliningrad, 236017, Russia*
[2]*Immanuel Kant Baltic Federal University, Kaliningrad, Russia*
[3]*Institute of Solar-Terrestrial Physics SB RAS, Irkutsk, Russia*
e-mail: maksim.klimenko@mail.ru

Abstract. This paper presents the investigation results of the dependence of the January daytime ionospheric $F2$ layer peak electron density (N_mF2) from solar activity ($<F_{10.7}>_{27}$) for 2012–2015. The ground-based ionosonde data depict following paradox: the daytime N_mF2 values in January of 2014 were less than those in January of 2015, whereas $<F_{10.7}>_{27}$ values in 2014 were greater than in those 2015. Constructing linear regressions for different data sets and analyzing the geomagnetic activity behavior we made a preliminary conclusion about a positive impact of geomagnetic activity on the January daytime N_mF2 values.

Introduction

The $F2$ layer peak electron density (N_mF2) is larger for higher solar activity and is proportional to sunspots number and the $F_{10.7}$ index (*Bryunelli and Namgaladze*, 1988). Solar activity dependence of ionospheric F region parameters diurnal and seasonal variations in the East-Siberian region is investigated in details by *Ratovsky et al.* (2015).

It was shown, that the higher solar activity leads to the growth rate of the N_mF2, which is greatest in the afternoon at winter solstice. Contrary, N_mF2 weakly depends on solar activity in the nighttime winter ionosphere which is caused by plasma flows from a plasmasphere. *Lei et al.* (2005) concluded that N_mF2 above Millstone Hill at 12:00 LT in winter increases linearly with increasing in solar activity proxy $F_{10.7}$ index. Hence, linear function can be used to represent the N_mF2 and proxy $F_{10.7}$ correlation. In this paper we examined N_mF2 dependence on the solar activity in January 2012–2015 at different locations.

Year	**$<F10.7>_{27}$**	**$<F10.7>_{81}$**	**$<Ap>_{27}$**	**$<Ap>_{81}$**
2012	128	124	7.3	6.5
2013	122	110	5.4	4.7
2014	149	154	4.7	6.8
2015	132	139	9.3	10.2

Table 1. 27 and 81 averaged values of the F10.7 and Ap indexes for 19 January 2012 – 2015

Observation data

We analyzed the daily $F_{10.7}$ index data from the web-site *http://lasp.colorado.edu/lisird/tss/noaa_radio_flux.html* and geomagnetic activity index *Ap* from the web-site *http://wdc.kugi.kyoto-u.ac.jp/kp/index.html for January–February 2012–2015.*

We obtained 27-day and 81-day averaged values of solar ($<F_{10.7}>_{27}$ and$<F_{10.7}>_{81}$) and geomagnetic ($<Ap>_{27}$ and $<Ap>_{81}$) activity indices for 19 January of each year (Table 1). $<Ap>_{27}$ and $<Ap>_{81}$ showed that the considered periods were geomagnetically quiet. We used $<F_{10.7}>_{27}$ to examine N_mF2 dependence on the solar activity. We used $<F_{10.7}>_{27}$ since it was similar to $<F_{10.7}>_{81}$ for the considered periods (see Table 1).

In order to estimate N_mF2 diurnal variation in the middle and subauroral latitudes dependence on solar activity we used the ionosonde data of seven stations from the Space Physics Interactive Data Resource(SPIDR) (*http://spidr.ngdc.noaa.gov*). We carried out the manual processing of SPIDR data due to various technical aspects of data recording. In addition we used the N_mF2 observation data from the Irkutsk and Kaliningrad ionosondes.

Station	**Latitude, degrees**	**Longitude, degrees**
Port Stanley	-51.7	-57.8
Jeju	33.5	126.5
I-Cheon	37.1	127.5
Boulder	40.0	-105.3
Rome	41.8	12.5
Pruhonice	50.0	14.6
Irkutsk	52.5	104.0
Kaliningrad	54.0	20.0
Moscow	55.5	37.3

Table 2. The list of stations

The latter were obtained from the manually scaled ionograms using interactive ionogram scaling software, SAO Explorer [*Reinisch et al.*, 2004; *Khmyrov et al.*, 2008] in the case of the Irkutsk ionosonde and PARUS software [*Karpenko and Manaenkova*, 1996] in the case of the Kaliningrad ionosonde. The geographic coordinates of all considered stations are presented in the Table 2. We obtained 27-daily median N_mF2 values for diurnal variations over all 9 stations for January 19 2012, 2013, 2014 and 2015. Diurnal variations in N_mF2 were obtained in terms of UT epoch and then transferred to local time (LT) diurnal variations.

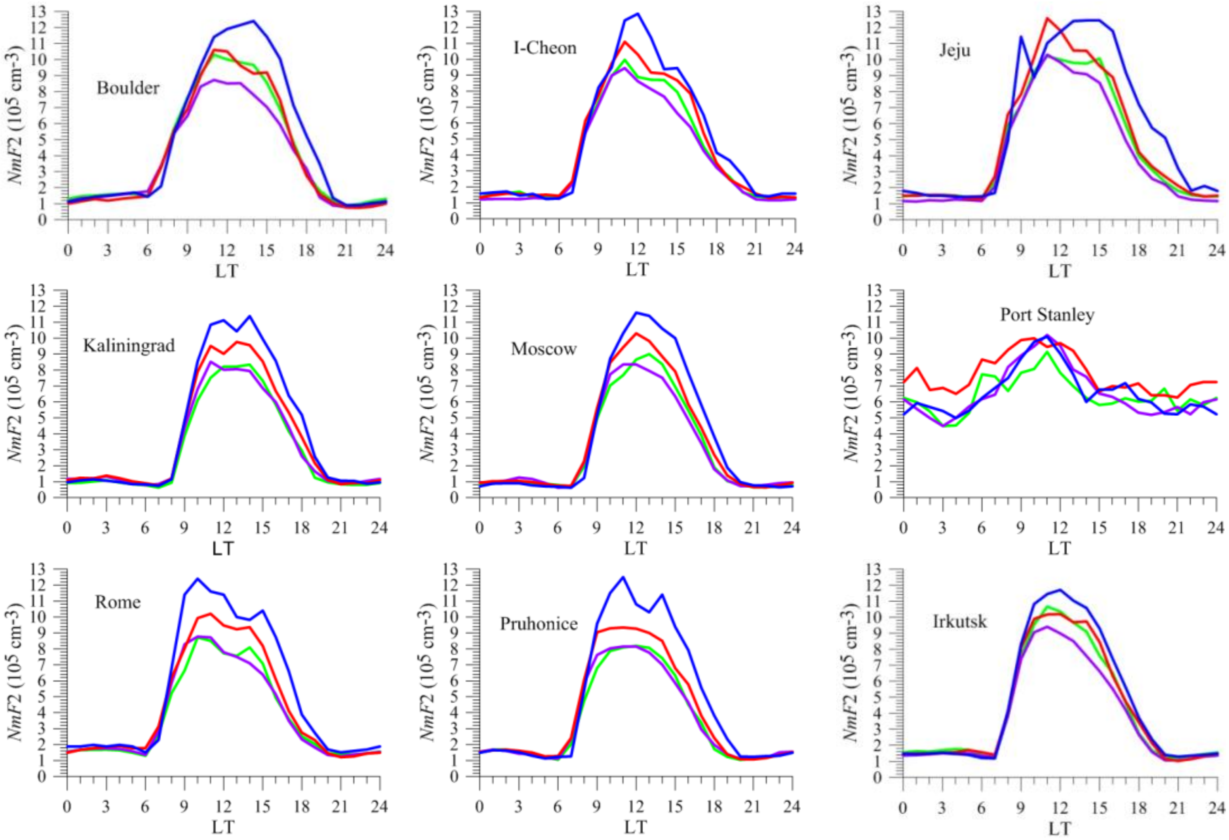

Figure 1. 27 day median *NmF*2 diurnal variation on 19 January 2012 (green), 2013 (purple), 2014 (red), 2015 (blue) for all considered stations.

Data analysis result

Figure 1 shows N_mF2 27-day median diurnal variations on 19 January for four years (2012–2015) over nine stations. It is evident that the solar activity has the greatest impact on the daytimeN_mF2 values. Over all stations (exclude Port Stanley) the following paradox is revealed: the greatest daytime N_mF2 values observed in January of 2015 do not correspond to the maximum in $<F_{10.7}>_{27}$ index (that observed on January 2014). As the following step, we calculated the 19 January daytime averaged (10:00–14:00 LT) N_mF2 values ($<N_mF2>$) for all the considered stations. On the basis of $<N_mF2>$ and $<F_{10.7}>_{27}$ values in a manner similar to (*Ratovsky and Oinats*, 2011; *Ratovsky et al.*, 2015) we constructed the linear regressions for different data sets: (1) “without 2014”; (2) “without 2015”; and (3) “all years”. Linear regression coefficients for all considered datasets are shown in the Table 3.

Fig. 2 shows the solar activity dependences of $<N_mF2>$ and results of all the obtained linear regressions. It is seen that: (1) the cases of “without 2015” and “all years” are close to each other and differ significantly from the case “without of 2014”; and (2) $<N_mF2>$ in 2015 has the greatest deviations from the linear regression compared to $<N_mF2>$ in other years in the “all years” case. Additionally, the linear regression in the “without 2014” case leads to negative (confusion) $<N_mF2>$ values at $<F_{10.7}>_{27}=70$ that is nor seen in linear regressions for the cases of “without 2015” and “all years”.

All these results demonstrate that $<N_mF2>$ on 19 January 2015 does no fit the solar activity dependence obtained for $<N_mF2>$ in other years, i.e. are anomalous from solar activity dependence view point.

Analyzing Fig. 3 and Table 1, we find that the January of 2015 is characterized by the greatest geomagnetic activity compared to other years. Considering a positive deviation of $<N_mF2>$ in 2015 from the linear regression in the “all years” case, we may assume a positive impact of geomagnetic activity on the January daytime N_mF2 values.

Conclusions

In this paper we have analyzed the solar activity dependence of the 2012-2015 N_mF2 winter diurnal variations and daytime N_mF2 values for different locations. We have shown that usually the daytime N_mF2 depends linearly on solar activity. The following paradox was discovered: the daytime N_mF2 values in January of 2014 were less than those in January of 2015, although the sor activity index $<F_{10.7}>_{27}$ in January of 2014 was more than that in January of 2015. This paradox was seen for all the considered stations (excluding Port Stanley).

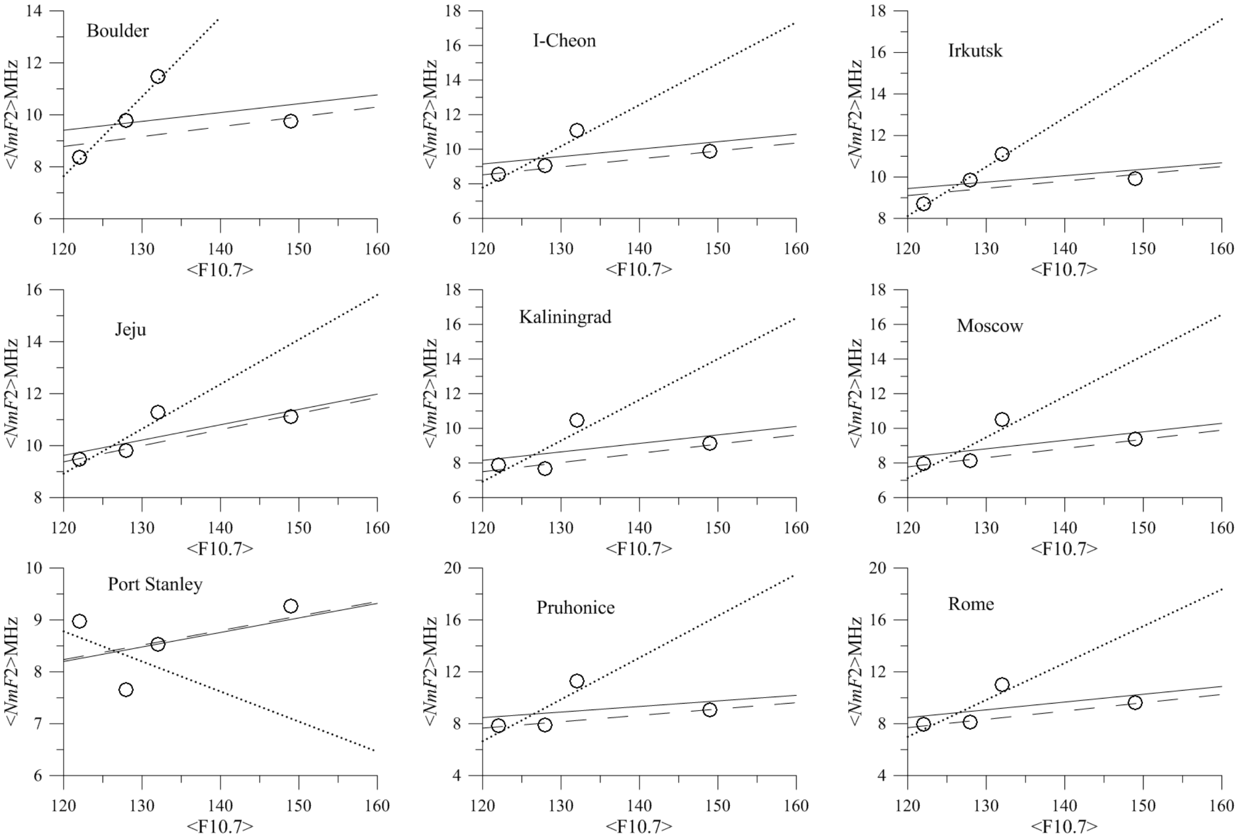

Figure 2. Daytime *NmF*2 dependence on the solar activity at different stations obtained by linear regression of data (presented by circles) for January 19 (1) 2012, 2013, 2015 (dotted line); (2) 2012, 2013, 2014 (dashed line); (3) all years in the consideration (solid lines).

Station	Linear regression coefficients for 2012, 2013, 2015		Linear regression coefficients for 2012, 2013, 2014		Linear regression coefficients for 2012–2015	
	b_0	b_1	b_0	b_1	b_0	b_1
Boulder	29.074	0.306	4.228	0.038	5.333	0.034
I-Cheon	-20.889	0.239	3.006	0.046	3.992	0.043
Irkutsk	-20.318	0.237	4.905	0.035	5.724	0.031
Jeju	-11.711	0.172	1.942	0.062	2.549	0.059
Kaliningrad	-21.387	0.236	1.143	0.053	2.277	0.049
Moscow	-21.191	0.236	1.423	0.053	2.454	0.049
Port Stanley	15.742	-0.058	4.878	0.028	4.841	0.028
Pruhonice	-31.981	0.322	1.789	0.049	3.316	0.043
Rome	-27.076	0.284	0.024	0.064	1.279	0.060

Table 3. Linear regression coefficients for different time intervals

Constructing linear regressions for different data sets and analyzing the geomagnetic activity behavior we made a preliminary conclusion about a positive impact of geomagnetic activity on the January daytime N_mF2 values. For testing this preliminary conclusion we plan to construct double linear regression of <N_mF2> from <$F_{10.7}$>$_{27}$ and <Ap>$_{27}$ using more years in the data sets.

Acknowledgments. Authors express the huge gratitude for use of the ionospheric observational data obtained from the SPIDR website *http://spidr.ngdc.noaa.gov/spidr/*. The solar activity index was obtained from the University of Colorado Boulder website *http://lasp.colorado.edu/lisird/tss/noaa_radio_flux.html*. The geomagnetic indices were obtained from the website *http://wdc.kugi.kyoto-u.ac.jp/*. This investigations were performed with financial support of the Russian Foundation for Basic Research Grants No. 14-05-00578 and 15-35-20364. This work was partially carried out within the project "Physical mechanisms of the reaction of the upper atmosphere and ionosphere on the processes in the lower atmosphere and on the Earth surface" (State task Education and Science Ministry of the Russian Federation, the competitive part of the task No 3.1127.2014/K).

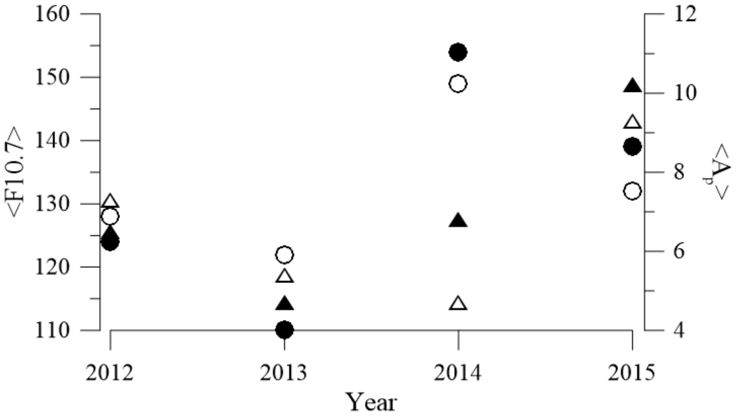

Figure 3. <F10.7>$_{27}$ (○), <F10.7>$_{81}$ (●), <Ap>$_{27}$ (Δ), <Ap>$_{81}$ (▲) for 19 January 2012–2015.

References

Bryunelli, B.E., Namgaladze, A.A. (1988). Physics of the ionosphere. M., Nauka, 526p. (in Russian).

Karpenko, A.L., Manaenkova, N.I. (1996). Nonlinear time series analysis of the ionospheric measurements. Geologishe Rundshau 85(1), 124–129.

Khmyrov, G.M., Galkin, I.A., Kozlov, A.V., et al. (2008). Exploring digisonde ionogram data with SAO-X and DID Base. In: Proc. AIP Conf. Radio Sounding and Plasma Physics 974, 175–185.

Lei, J., Liu, L., Wan, W., and Zhang, S.-R., (2005). Variations of electron density based on long-term incoherent scatter radar and ionosonde measurements over Millstone Hill. Radio Sci. 40, RS2008, doi: 10.1029/2004RS003106.

Ratovsky, K.G., Oinats, A.V., Medvedev, A.V. (2015). Similitaries and differences between regular variations of F2-layer parameters of the polar and midlatitude ionosphere in east Siberian sector. Solar-Terrestrial Physics 1(2), 70–79.

Ratovsky, K.G., Oinats, A.V. (2011). Local empirical model of ionospheric plasma density derived from digisonde measurements at Irkutsk. Earth Planets Space 63(4), 351–357.

Reinisch, B.W., Galkin, I.A., Khmyrov, G., et al. (2004). Automated collection and dissemination of ionospheric data from the digisonde network. Adv. Radio Sci. 2, 241–247.

Rishbeth, H., Müller-Wodarg, I.C.F. (1999). Vertical circulation and thermospheric composition: a modeling study. Ann. Geophysical 17, 794–805.