Morphology of Midlatitude Summer Nighttime Anomaly in NmF2 above Alma-Ata

Artur Yakovets, Galina Gordienko, Beibit Zhumabayev, and Yuri Litvinov

Institute of Ionosphere, National Center for Space Research and Technology, Almaty, Kazakhstan

(artyak40@mail.ru)

Abstract. The morphology of the midlatitude summer nighttime anomaly (MSNA) in the diurnal behavior of the electron concentration maximum in the F2 layer in various seasons and at various solar activity levels was studied with the use of vertical sounding data in Almaty in 1999, 2008, 2011, and 2012. It was shown that the anomaly is manifested most distinctly in the summer months (June–August) and disappears in the equinox months (March, September). The maximum value of the electron concentration falls on the solar zenith angles, which correspond to the cessation of the arrival of ionizing radiation at the heights of the F2-layer maximum. The anomaly is clearly manifested in the solar activity minimum and barely seen in the maximum. It was shown that the summer anomaly parameters at the boundary of the northeastern Asia (Almaty, 76 55′ E) insignificantly change as compared to the parameters of its center (Japan, 130 E). Mechanisms of anomaly formation, as well as of its diurnal and seasonal behavior, are discussed.

1 Introduction. It is widely known that diurnal variations in the electron concentration in the maximum of the midlatitude i[...] ne behavior typical for the Chapman layer governed by the solar radiation f[...]

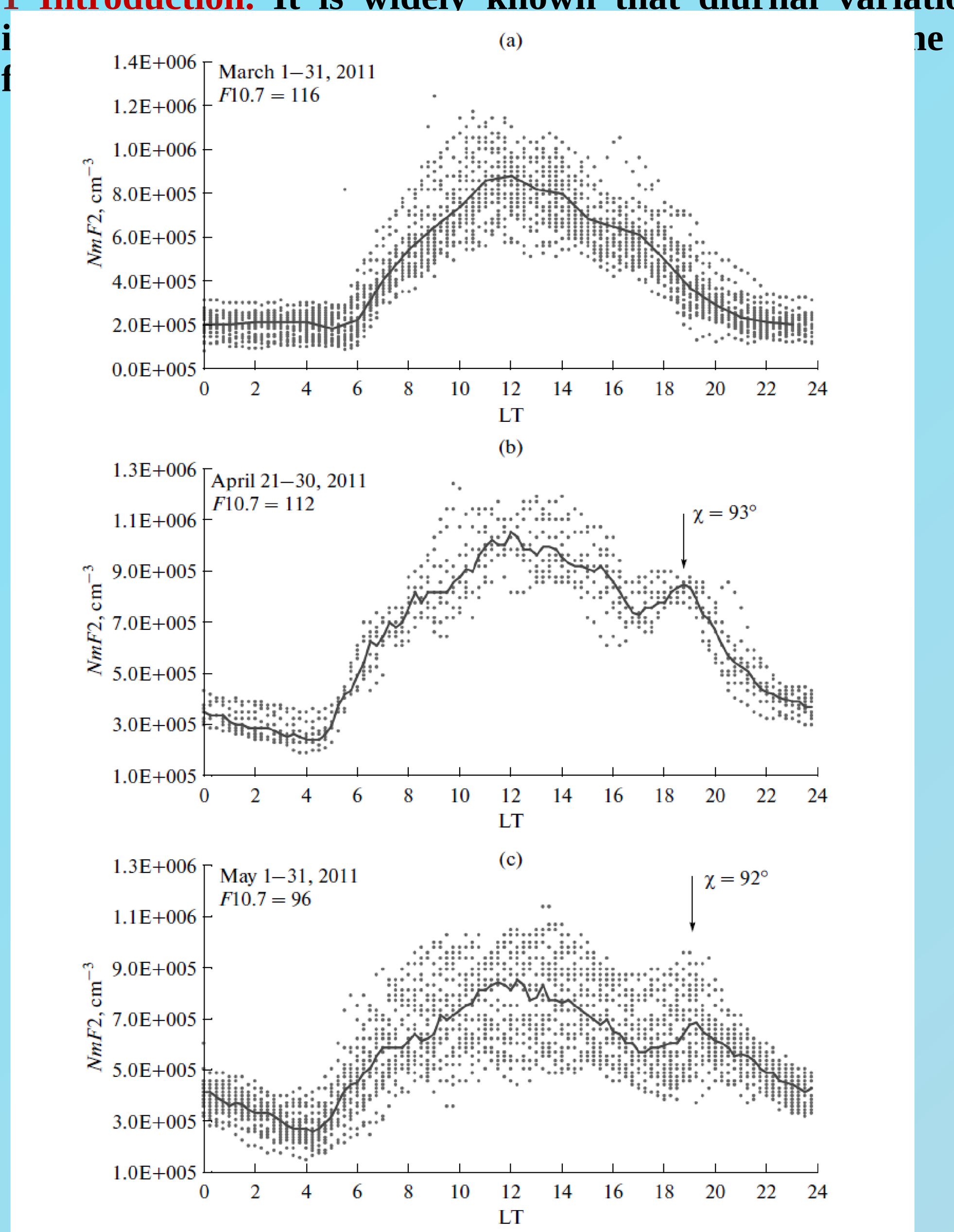

Figure 1. Diurnal behavior of the electron concentration in the F2-layer maximum in (a) March 2011, (b) April 2011, and (c) May 2011.

effect was detected over the Antarctic according to data from groundbased vertical ionospheric sounding [1]. A similar effect (an evening increase in NmF2 in the summer months) was detected also in the Northern Hemisphere [2]. The anomalies in the diurnal behavior in both the Northern and Southern hemispheres obtained the joint name of midlatitude summer nighttime anomaly (MSNA) [3]. The maximum amplitudes of the effect are observed at longitudes corresponding to the maximum distance between the geomagnetic and geographic equator. In the North-ern Hemisphere these longitudes are located near 135 E (the northeastern Asia anomaly with a maximum amplitude at the longitudes of Japan and Okhotsk Sea [3]). Alma-Ata (76 55′ E) is located at the western boundary of the longitudinal sector of the northeastern Asia anomaly, so studying the characteristics of the latter at this longitude presents substantial interest. Our goal was to analyze the MSNA parameters over Alma-Ata, including their diurnal behavior, seasonal variations, and dependence on solar activity.

2 Observation results and discussion. To analyze the MSNA evolution as a function of a season, we drew the diurnal behavior of the electron concentration for March, April, May, June–July, August, and September 2011 (Fig. 1). The points show separate NmF2 measurements. The solid curve shows the median. The vast majority of data of the analyzed electron concentration measurements was obtained under low magnetic activity (Dst > –50 nT). Measurements during which moderate and high magnetic activity (Dst ≤ –50 nT) was observed were rejected from the analysis. The monthly mean values of the solar radio emission flux at a wave of 10.7 cm for each month and the solar zenith angles (χ) calculated for the middle of the analyzed month corresponding to the peaks of the evening maximum in NmF2

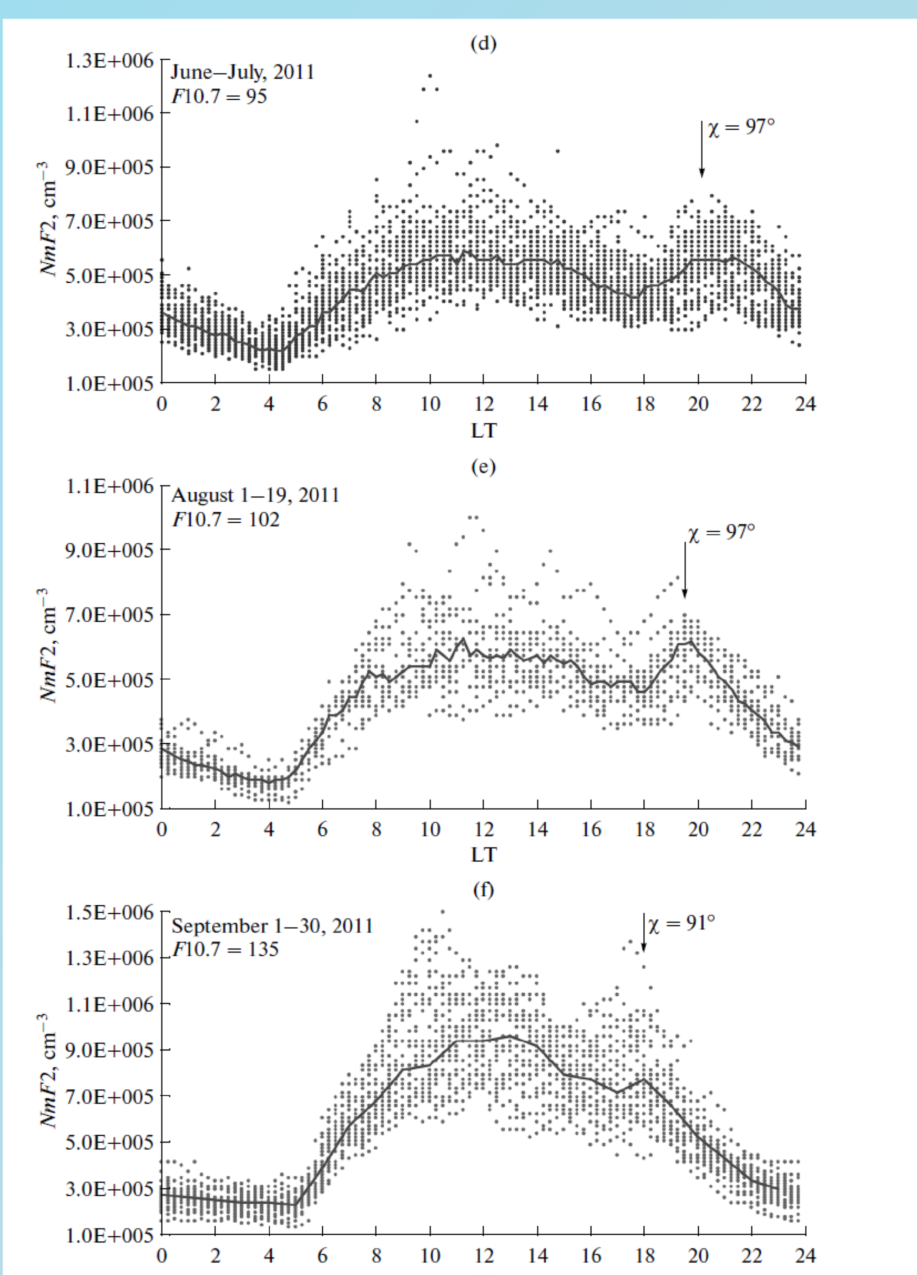

Figure 1. (continuation). Diurnal behavior of the electron concentration in the F2-layer maximum in (d) June–July 2011, (e) August 2011, and (f) September 2011.

are shown on the margin of the figure. The anomaly presents the effect of a positive deviation in NmF2 in the evening hours (~2000 LT in summer) from the smooth diurnal behavior. Now we consider the anomaly manifestation beginning from the spring equinox month and ending by the fall equinox month. In March (Fig. 1a), the diurnal behavior of the median shows no pronounced evening peak. It appears sharply in April (Fig. 1b). In May (Fig. 1c), the evening maximum in NmF2 is approximately the same as in April, whereas in June–July the positive deviation in NmF2 in the evening hours increases (Fig. 1d). A strong positive deviation in NmF2 remains in August (Fig. 1e). In September (Fig. 1f) the evening maximum differs little from the diurnal fluctuations in the median caused by statistical scatter. The time corresponding to the evening maximum is shown in the figures by vertical arrows. The sunset times and the solar zenith angle change rates were taken from astronomical tables, and the zenith angles χ corresponding to the evening maximum were calculated. All of the zenith angles correspond to the position of the Sun below the mathematical horizon, when the ionizing radiation almost ceased traveling to the F2-layer heights. The dependence of the anomaly parameters on solar activity can be seen in Fig. 2, in which the sounding data in the period of the summer solstice for low (2008) (Fig. 2a), moderate (2012) (Fig. 2b), and high (1999) (Fig. 2c) solar activity are shown. It follows from the graphs that the minimum manifestation of the summer anomaly corresponds to the maximum solar activity. We then compared the results obtained by us in 2008 to the measurements conducted in Japan in July 2008 at the center of the northeastern Asia anomaly zone [4]. These measurements were conducted by radio occultation, which makes it possible to obtain the electron concentration profile beginning from the bottom layer and up to heights substantially exceeding the height of the layer maximum. Thampi et al. [4] showed that the local time corresponding to the night maximum peak depends on geographic latitude (Fig. 3): the time shifts towards midnight at the increase in latitude. For the geographic latitude of 45 N, which almost coincides with the latitude of Alma-Ata,

this time was found to equal 2030 LT, which coincides with the time obtained by us. The deviations in NmF2 in evening hours from the smooth diurnal behavior were also similar. This shows that the anomaly parameters at the zone boundary (Alma-Ata, 76 55′ E) vary insignificantly relative to its center (130 E).

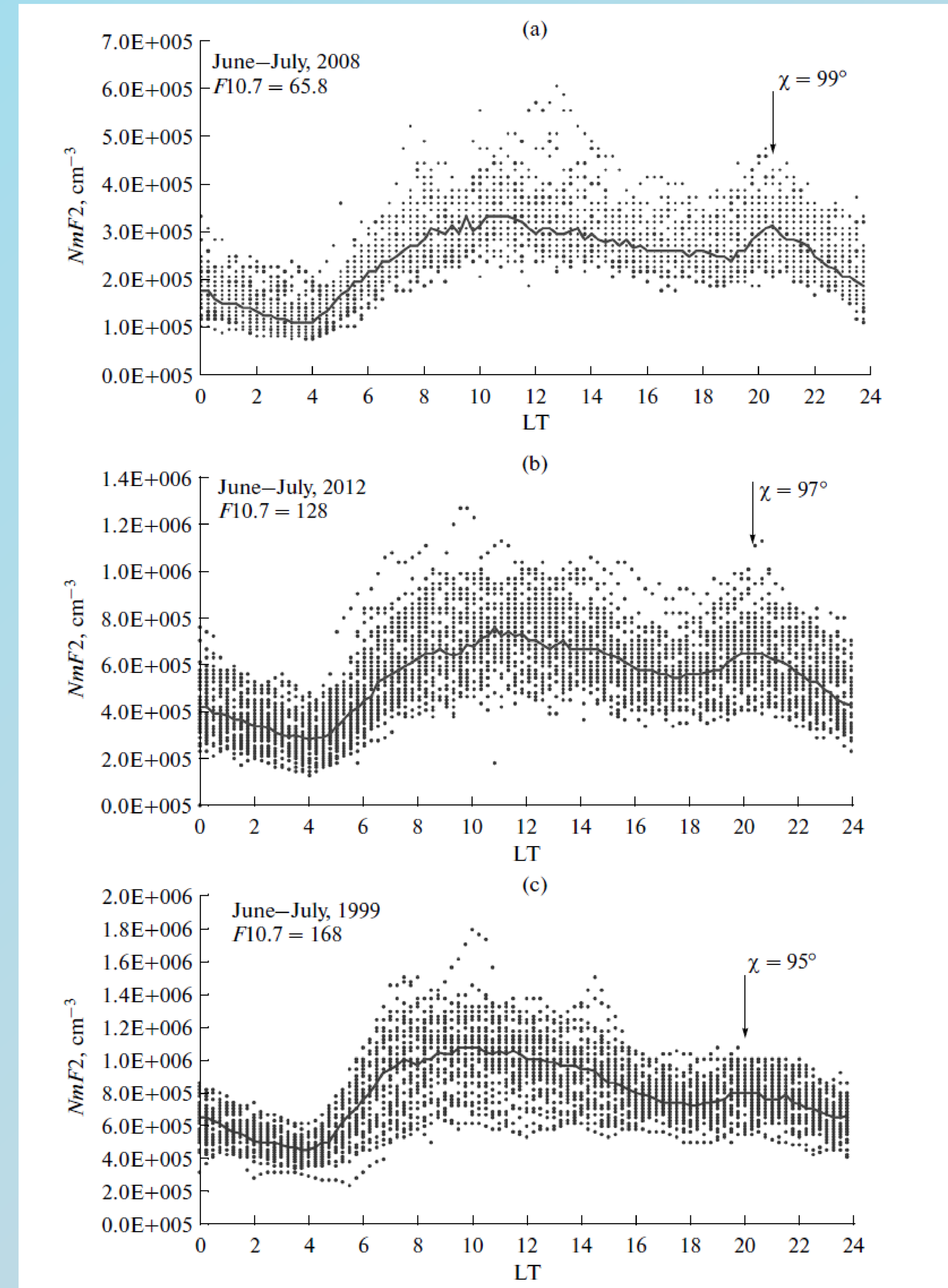

Figure 2. Diurnal behavior of the electron concentration in the F2-layer maximum in June–July of (a) 2008, (b) 2012, and (c) 1999.

Two factors determining the anomaly formation in the summer months are considered in the literature. First [4], the meridional wind changes its direction from polarward to equatorward much earlier in summer at the middle latitudes than in other seasons (around 14.30 LT), when the photoionizing radiation flux is still high. That is why photoionization, in combination with the rise of the ionosphere to the heights where the recombination rate is low, leads to the formation of an evening increase in NmF2. Second, in addition to the factor of an early change in the thermospheric wind direction, seasonal variations in the meridional wind velocity are manifested in the fact that the equatorward meridional wind has the maximum and minimum velocities in the summer and winter hemispheres, respectively, at night [5]. In the equinox periods, the velocity of the equatorward neutral wind has intermediate values. Now we consider possible causes of the obtained good correspondence between the anomaly parameters over Japan and Alma-Ata. Knyazeva et al. [6] presented calculations of the global distribution of the electron concentration using the Upper Atmosphere Model (UAM); the calculations included the thermosphere, ionosphere, and plasmasphere and took into account the displacement of the geomagnetic and geographic poles of the Earth. The model calculations have shown that the anomaly in the Northern and Southern Hemispheres is formed at longitudes at which the geomagnetic equator is shifted maximally relative to the geographical one into the summer hemisphere. An important role is played in the formation of the longitudinal variation in MSNA by the longitudinal dependence of the vertical component Vzi of the velocity of ion transport by the meridional neutral wind (Vxn), which is approximately equal to Vzi ≅ VxncosIsinI, where I is the inclination of the magnetic field.

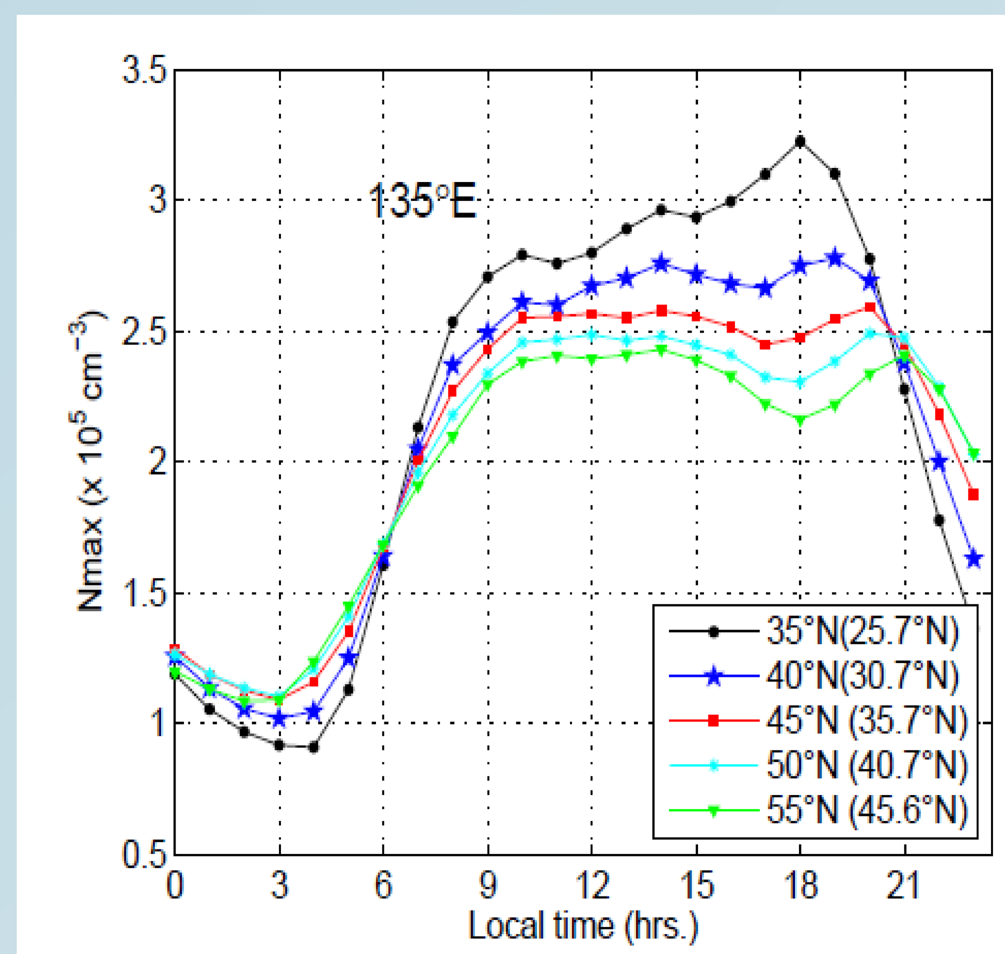

Figure 3. Local time variation of Nmax at various latitudes during July 2008, obtained from F3/C measurements corresponding to 135 E Longitude (Thampi et al., 2011).

The longitudinal dependence of the product cosI sinI as calculated for the Southern Hemisphere showed that, at the same Vxn, the vertical component can differ almost by a factor of two between the longitudes with maximum and minimum values of cosIsinI. Such a substantial change in cosIsinI is caused by a substantial change in the magnetic inclination I with longitude in the Southern Hemisphere. At the same time, in the Northern Hemisphere, the longitudinal variations in I are substantially lower [7], so the variations in cosIsinI are not as strong. That can apparently explain the results of our comparison, which has shown an insignificant decrease in the anomaly amplitude upon a substantial change in longitude. It follows from Fig. 2 that the anomaly is better pronounced in the solar activity minimum. It is explained by the fact that the velocity of the meridional thermospheric wind is lower under high solar activity than under low activity due to an increase in the friction force between the neutral component and ions [6].

So, it was shown that the anomaly is not seen in the equinox months in the diurnal behavior of the electron concentration maximum in the F2 layer. The maximum effect of the anomaly is seen in the summer months (July–August). The maximum value of the electron concentration in the evening peak corresponds to the solar zenith angles, when the ionizing radiation almost ceases to reach the heights of the F2-layer maximum. The anomaly is distinctly manifested in the solar activity minimum but scarcely seen in the solar maximum. It was shown that the parameters of the summer anomaly at the boundary of the northeastern Asia zone (Alma-Ata, 76 55′ E) change insignificantly as compared to the parameters at its center (Japan, 130 E).

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