

# ON THE RELATION OF CERTAIN PARAMETERS OF THE TROPOSPHERE AND IONOSPHERE TO CHANGES IN SOLAR-WIND VELOCITIES

GEOPHYSICS

1968

SovietRxiv

---

View the original and related papers at <https://sovietrxiv.org/items/ru-196801.18868>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

## Abstract

## Full Text

UDC 550.2

*GEOPHYSICS*

R. V. SMIRNOV

# ON THE RELATION OF CERTAIN PARAMETERS OF THE TROPOSPHERE AND IONOSPHERE TO CHANGES IN SOLAR-WIND VELOCITIES

*(Presented by Academician V. V. Shuleikin, 22 VI 1967)*

In accordance with <sup>(1)</sup>, new relationships have been found between changes in solar-wind velocities (s.w.v.) and fluctuations of meteorological parameters in certain regions on various isobaric surfaces. The disturbance of the ionospheric *F2* layer also correlates well with the changing character of the solar plasma beyond the outer boundary of the head shock wave. Some of the corresponding data are given below.

Figure 1 shows fluctuations of the s.w.v. measured by a satellite of the "Vela-2" series <sup>(2)</sup> over four solar rotations Nos. 1793–1796. Each rotation is divided into four sectors with a predominant polarity of the interplanetary magnetic field. In drawing the preliminary boundaries of the sectors, account was taken of data on the stability of an active region on the Sun in its magneto-optical or magnetic phase, on the distribution of s.w.v. within the sector and the geomagnetic activity associated with them, and on the presence of recurrent *sc* and *si*. For reference, measurements of the polarity of the interplanetary field by the "IMP-1" satellite and the "Mariner-4" station <sup>(3)</sup> at the beginning and end of 1964 were used. The preliminary sector boundaries and the polarity of the interplanetary field indicated in <sup>(1)</sup> were confirmed with the use of data from the "IMP-2" satellite <sup>(4)</sup>.

Curve 3 in Fig. 1, characterizing fluctuations of surface atmospheric pressure (1200 UT), was obtained by averaging data for 7 Kuril-Kamchatka regions. According to <sup>(5)</sup>, the center of one of the zones of solar-induced cyclogenesis is located here. Like the temperature field of the troposphere of the Black Sea coast <sup>(1)</sup>, pressure changes in the regions under consideration, as is seen in Fig. 1, are stochastically related to fluctuations of solar-wind velocities. This relationship, as in <sup>(1)</sup>, is of an inversion character—the sign of the relationship changes with a change in the polarity of the interplanetary field. Passage of a sector boundary does not every time cause a change of sign of the relationship in this region (11 VIII, 24 X), but if inversion occurs, it is observed after passage of the

Figure 1

Figure 1: Figure 1

boundaries (3 VIII, 31 VIII, 6 IX, 27 IX, 3 X, 17 X). The correlation coefficients  $r$ , characterizing the closeness of the negative and positive relationships and obtained by combining the coefficients, are respectively  $-0.51$  and  $0.56$ . Using Fisher's transformation, we calculate the values  $z$ ,  $\sigma_z$ , and the probabilities  $P$  of random deviation of the correlation coefficients to the indicated values of  $r$ : negative relationship  $z = 0.563$ ,  $\sigma_z = 0.127$ ,  $P < 0.0001$ ; positive relationship  $z = 0.633$ ,  $\sigma_z = 0.183$ ,  $P = 0.0006$ . The obtained values of  $P$  indicate the high significance of the correlation coefficients. In Fig. 1 one can clearly see not only the 27-day recurrence of pressure extrema corresponding to high-speed plasma streams or periods of quiet solar wind, but also the 27-day recurrence of inversions of the sign of the relationship; moreover, some sector boundaries proved in this respect to be more effective for the given regions (the boundary of sectors *I–II* and *II–III*), while others did not cause such an inversion (the boundary of sectors *III–IV*).

Fig. 1 also shows curve 2 of the deviations of the critical frequencies  $f_0$  of the ionospheric  $F_2$  layer from the monthly median in percent (Moscow). The deviations were averaged over 10–14 h *LT*. A comparison of curves 1 and 2 shows that the disturbance of the  $F_2$  layer correlates with changes in the solar-wind velocity. The relation is characterized by a negative sign, with the exception of sector *II* of solar rotation No. 1796, where, after the passage of the sector boundary on 24 X, an inversion of the sign of the relation is observed. The correlation coefficient, calculated by means of “variable differences” (to eliminate long-period variations), is equal to  $-0.57$ ;  $z = 0.648$ ,  $\sigma_z = 0.115$ ,  $P < 0.0001$ . For this region and period, the decrease in  $f_0F_2$  coincides in time with the flow around the Earth's magnetosphere by fast plasma streams; the increase in  $f_0F_2$  is associated with periods of quiet solar wind and the passage of sector boundaries. Although some  $\Delta f_0F_2$  do not exceed 5–10% and therefore cannot be counted among ionospheric disturbances, it is important to note that even small fluctuations of the electron density from day to day are closely connected with changes in the parameters of undisturbed solar plasma. The disturbance of the nighttime ionosphere also correlates well with the solar-wind velocity, but with the corresponding curve shifted by several hours relative to curve 2.

The data of *Mariner-2* and *Pioneer-6* on the solar-wind velocity were also compared with  $\Delta f_0F_2$  (Moscow). For the period of operation of *Mariner-2* <sup>(6)</sup>, more frequent inversions of the sign of the relation are characteristic, with a predominance in duration of a positive relation. During the period of measurements by *Pioneer-6* of the solar-wind velocity <sup>(7)</sup>, a clearly expressed positive relation is noted. Analysis of these materials leads to the conclusion that the character of the relation of ionospheric–

**Fig. 1.** 1 –curve of the solar-wind velocity. The dashed line corresponds to the

satellite being located in the shadow zone inside the Earth' s magnetosphere; 2 –curve of deviations of the critical frequencies from the monthly median in % ( $\Delta f_0 F2$ ) at the Moscow station, averaged over 10–14 h *LT*; 3 –curve of surface atmospheric pressure at 1200 *UT*, averaged over 7 Kuril–Kamchatka weather stations.

Vertical solid lines –boundaries of sectors of the interplanetary field according to the data of the “IMP-2” satellite (<sup>4</sup>); dashed lines –assumed sector boundaries. For each solar rotation the polarity of the interplanetary field is shown at the top. The dashed sector boundaries correspond to the assumed polarity of the interplanetary field. The hatched areas denote the absence of measurements on “IMP-2.” *I–IV* –conventional numbers of sectors.

...and magnetic disturbances in the given region depends on the sign of the correlation of the solar-wind speed and the criterion of ionospheric disturbance. With a negative correlation (see Fig. 1), increases of  $f_0 F2$  during periods of quiet solar wind occur against a background of an undisturbed geomagnetic field. The predominance of this type of correlation (negative disturbances) during the periods of maximum and decline of solar activity at high and middle latitudes provided the basis for the conclusion (<sup>8</sup>) that positive disturbances are not connected with geomagnetic activity. On the other hand, with a positive correlation, an increase in  $K_p$  during the passage of high-speed streams will correspond to an increase in  $f_0 F2$ , and when  $\Delta f_0 F2$  exceeds +20%, to positive disturbances. If the sign of the correlation between solar-wind speed and  $\Delta f_0 F2$  is determined chiefly by the sector structure and polarity of the interplanetary field, then this implies the fundamental importance of studying, in this aspect, the interaction of the interplanetary field with the Earth' s magnetosphere.

As can be seen in Fig. 1, before the Earth' s magnetosphere enters the fast plasma jet there is an increase in  $f_0 F2$ , after which a sharp drop in  $f_0 F2$  and the development of negative disturbances are observed. When the corresponding  $\Delta f_0 F2$  are large (score 2–3), their combination may constitute a two-phase disturbance. Such disturbances may include (in terms of the disturbance of the nighttime ionosphere) the disturbances of 37 VIII–3 IX and 19–20 X. More often, however, positive deviations preceding negative disturbances do not exceed 5–10%. From the detailed agreement of curves 1 and 2 it also follows that the intensity and character of the  $D_{st}$ -variation of  $f_0 F2$  are determined to a considerable extent by the distribution of solar-wind speed within the given sector.

Consideration of the time course of the mean drift velocities of ionospheric irregularities in *F2* and *E* (Katsiveli station, Crimea) shows a tendency toward a sharp increase in drift velocities during periods when the Earth is in streams of high-speed plasma. The reversal of the sign of the ionospheric disturbance and of the dependence  $K_p$ –drift velocity upon transition from middle latitudes to equatorial latitudes (<sup>9, 10</sup>) also testifies in favor of the existence of a common cause for the increase in disturbance and drift velocities in the ionosphere.

The existence of a correlation between solar-wind speed and  $\Delta f_0 F2$  could have been expected on the basis of the close correlation between solar-wind speed and the  $K_p$  index, and between  $K_p$  and  $\Delta f_0 F2$ . The pronounced “responsiveness” of the ionosphere even to small changes in solar-wind speed permits one to suppose the existence of a deep causal connection between the phenomena. The largest oscillations of  $f_0 F2$  and  $h' F2$  are observed in the auroral zone, which is tied to coastal regions of the sea <sup>(11)</sup>. From there, acoustic gravity waves <sup>(12)</sup>, excited when the Earth passes through the front of a shock wave, propagate to low latitudes.

In the example considered, the influence of the sector structure of the interplanetary field is manifested less in the ionosphere than in the troposphere. For the period of operation of *Mariner 2*, a greater “sensitivity” of the ionosphere is characteristic.

Measurements of solar-wind speed and of the positions of the magnetopause and bow shock, carried out on satellites of the *Vela 2* series, showed that displacements of the magnetopause and shock wave, occurring at high speed, are connected with changes in the pressure of the solar plasma and correlate with the  $K_p$  index, and consequently with solar-wind speed <sup>(13)</sup>. When the shape and dimensions of the magnetosphere change, hydromagnetic and acoustic gravity waves are excited, whose action leads to an intensification of circulation in the upper atmosphere. Dissipative effects of magnetohydrodynamic waves in the ionosphere manifest themselves in disturbances of the temperature regime and corresponding changes in the effective recombination coefficient and the rate coefficient of photochemical reactions <sup>(14)</sup>. Spatial displacements of the shock wave and magnetopause will probably promote the excitation of internal gravity waves, manifested in the dis—

propagation of ionospheric disturbances in the vertical and horizontal directions. The rapid transmission of disturbances from the upper atmosphere into the stratosphere and troposphere causes the activation of solar-conditioned centers of atmospheric action and subsequent changes in the macrosynoptic process. Energy considerations lead one to suppose the existence of an amplifying mechanism in the effect of the solar wind on the Earth’s magnetosphere, in which changes in the solar-wind velocity are the modulating agent <sup>(15)</sup>. To this it should be added that the polarity of the interplanetary field possibly plays the role of an external controlling voltage in a trigger-type release mechanism, whose action determines the direction of a number of geophysical processes.

Marine Hydrophysical Institute  
Academy of Sciences of the Ukrainian SSR

Received  
23 VI 1967

## CITED LITERATURE

- <sup>1</sup> R. V. Smirnov, DAN, 175, No. 1 (1967).
- <sup>2</sup> R. Lust, The Properties of the Interplanetary Medium, Pap. presented at the Intern. Symposium on Solar-Terrestrial Relationships, Belgrad, Yougoslavia, 29 VIII–2 IX, 1966.
- <sup>3</sup> P. J. Coleman, L. Davis et al., J. Geophys. Res., 71, No. 11, 2831 (1966).
- <sup>4</sup> D. H. Fairfield, N. F. Ness, Magnetic Field Measurements with the IMP-2 Satellite, Preprint, 1966.
- <sup>5</sup> T. Asakura, A. Katayama, Pap. on Meteorol. Geophys., 9, No. 1 (1958).
- <sup>6</sup> M. Neugebauer, C. W. Snyder, J. Geophys. Res., 71, No. 19, 4469 (1966).
- <sup>7</sup> A. J. Lazarus, H. S. Bridge, J. Davis, J. Geophys. Res., 71, No. 15, 3787 (1966).
- <sup>8</sup> M. P. Kiyanovskii, N. V. Mednikova, *Geomagnetism and Aeronomy*, 3, No. 4, 769 (1963).
- <sup>9</sup> R. A. Zevakina, E. V. Lavrova, L. N. Lyakhova, *Fundamentals of Forecasting Ionospheric-Magnetic Disturbances and the Service of Short-Term Radio Forecasts*, Moscow, 1967.
- <sup>10</sup> S. F. Mirkotan, Yu. V. Kushnerevskii, *Inhomogeneous Structure and Motions in the Ionosphere*, Moscow, 1964.
- <sup>11</sup> Yu. A. Nardubovich, *Beryozovy Effect in Polar Auroras*, Moscow, 1967.
- <sup>12</sup> V. M. Shashunkina, *Geomagnetism and Aeronomy*, 6, No. 1, 146 (1966).
- <sup>13</sup> J. T. Gosling, J. R. Asbridge et al., J. Geophys. Res., 72, No. 1 (1967).
- <sup>14</sup> V. P. Kuleshova, E. I. Mogilevskii, *Geomagnetism and Aeronomy*, 5, No. 5, 850 (1965).
- <sup>15</sup> Brian J. O' Brien, Interrelations of Energetic Charged Particles in the Magnetosphere, Invited Pap. Presented at the Intern. Symposium on Solar-Terrestrial Phys., Belgrade, Yougoslavia, 29 VIII–2 IX, 1966.

*Note: Figure translations are in progress. See original paper for figures.*

*Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.*