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GEOPHYSICS

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TRANSFORMATIONS OF FORMS OF TROPOSPHERIC CIRCULATION IN CONNECTION WITH THE MACROSTRUCTURE OF THE SOLAR WIND

(Presented by Academician V. V. Shuleikin on 9 X 1968)

In continuation of ([1], [2]), changes in the general circulation of the troposphere are considered that are causally connected with the Earth's being in a fast quasi-stationary stream and in the quiet solar wind, i.e., that are determined by its macrostructure. The existence of the latter determines, by virtue of the variable energy flux (equal to the pressure) of the solar plasma, dynamic disturbances of the Earth' s magnetosphere. The interaction of the magnetospheric plasma with the inhomogeneous solar wind is reflected in the disturbance not only of the upper atmosphere (including the ionosphere ([2])), but also of the troposphere ([1], [2]). The density of the solar-wind energy flux depends mainly on the magnitude of its velocity; consequently, the distribution of the energy-flux density within sectors of the interplanetary field may be approximated by the distribution of solar-wind velocities (s.w.v.).

The circulation of the troposphere and the transformation of its forms are the result of the joint action of heat engines ([3]), the Earth' s rotation, cyclonic activity on tropospheric fronts, and solar activity. To single out the role of the latter, it is necessary to select among solar factors the most identical ones, i.e., to satisfy the following conditions: 1) quasi-stationarity of the streams; their sources, according to E. R. Mustel' s concept, are centers of activity in the magnetic-optical or magnetic phases ([4]); 2) their linkage to one active longitude, i.e., consideration of a 27-day sequence; 3) the presence of close active longitudes in the northern and southern hemispheres of the Sun; 4) absence of the effect of neighboring centers of activity; 5) significant differences in s.w.v. values in the fast stream and in the quiet wind; 6) in connection with ([1], [2]), membership of the selected sequence in a sector of the interplanetary field of one polarity. A joint analysis was made of solar synoptic charts, data on coronal radiation at λ 5303 Å, results of direct measurements of the plasma and field, as well as ionospheric-geomagnetic data, and a sequence satisfying the required conditions was identified (beginning 30 VIII-8 IX 1962, ending 23-31 X 1964). The sequence maintained stability* over 30 solar rotations: Nos. 1767-1796. The use of rocket and satellite data on the polarity of the interplanetary field** made it possible to "tie" this sequence to the sector with positive polarity. The preservation of polarity can be explained by the predominant activity of the Sun' s northern hemisphere and by the propagation of the corresponding local magnetic fields into the other hemisphere ([6]). The results of direct measurements of the s.w.v. were published for rotations Nos. 1767-1771 (Mariner 2) ([7]) and Nos. 1793-1796 (Vela 2) ([8]). For the remaining rotations, the s.w.v. was obtained according to the dependence ([7]) $v =$

* In ([5]) this sequence is assessed as the most stable.
** AMS and AES data were used. In the absence of direct field measurements, the boundaries were found in accordance with the method indicated in ([1], [2]).

$$= 8.44 \sum K_p + 330,$$

where v is the solar-wind velocity, and $\sum K_p$ is the daily sum of the three-hour K_p indices of geomagnetic activity.

Next, using the daily synoptic maps of AT_{500} for the Northern Hemisphere, published by the Hydrometeorological Center, elementary synoptic processes (e.s.p.) were identified for the Atlantic-Eurasian sector (sector I), and the forms of circulation were typified according to the classification of G. Ya. Vangengeim and A. A. Girs (processes of the western W, meridional C, and eastern E forms in sector I, and the corresponding forms , M_1, M_2 in the Pacific-American sector (sector II)). In doing so, according to (9–12), account was taken of the space-time features of the transformation of circulation forms, depending on the circulation epoch and its stages, the intra-annual changes of macroprocesses, the type of circulation in sector II, etc.

The most significant changes in the pressure of solar plasma on the Earth' s magnetosphere occur when the Earth enters the leading part of a quasi-stationary stream. During this period, as follows from (13), the plasma velocity increases sharply, while its density has not yet fallen. In this connection, in studying the transformation of circulation forms, the days with the most significant daily increase in solar-wind velocity (Δv) were selected as reference dates.

Analysis of the AT_{500} maps shows that, for all sequences, 1-2 days after the reference date there is an intensification of meridional motions and the formation of upper-level ridges and troughs. In 27 cases out of 30, development of the C-form* was observed, and in three cases, of the E-form. The probabilities P of intensification of meridional circulation for different shifts Δt relative to the zero reference day in the interval $0 \div +5$ days are, respectively:

$$P_0 = 0.10, \quad P_{+1} = 0.54, \quad P_{+2} = 0.20, \quad P_{+3} = 0.10, \quad P_{+4} = 0.03, \quad P_{+5} = 0.03.**$$

The magnitude of Δt is determined by the persistence of circulation forms depending on the stage of the epoch and intra-annual transformations, as well as by the magnitude of Δv and the character of its subsequent change. In general, Δt tends to increase from winter to summer and to decrease as Δv increases.

The strengthening of meridional motions at the 500 mb surface is associated with the emergence of long waves. The Earth' s exit from the fast stream (a fall in solar-wind velocity) leads to a decrease in wave lengths and to their displacement eastward with velocity (14)

$$c = u - \beta L^2 / 4\pi^2,$$

where u is the velocity of the zonal flow, β is the rate of change of the Coriolis parameter in the northern direction, and L is the wavelength. If, during the increase in solar-wind velocity, meridional motions were strongly expressed, then during the fall in solar-wind velocity baric formations often split off: from a ridge—an anticyclone, from a trough—a cyclone. With a further fall in solar-wind velocity they become elongated in the latitudinal direction. The planetary upper frontal zone of the temperate latitudes, which bent around the upper ridges and troughs when a meridional type of circulation arose, during the Earth' s exit from the fast stream tends to become elongated in the latitudinal direction and shifts southward.

All this indicates activation of meridional forms when the velocities in the stream flowing around the Earth' s magnetosphere increase, and their transformation into a zonal form when the solar-wind velocity falls. Thus, in short-period transformations of macroprocesses, the effect of strengthening of meridional forms of circulation with increasing solar activity, found by A. A. Girs for multiyear cycles (12), is detected.

The character of the change in solar-wind velocity in the fast stream is of great importance. Thus, the presence in the stream of two maxima of solar-wind velocity and of a small minimum between them leads successively to blocking of the zonal and strengthening of meridional motions, which are replaced by short-period—

* Included here are four cases of development of the intermediate form $C + E$.

** These data agree with the results of processing about 100 cross-correlation functions, calculated with the aid of the electronic analyzer of random processes (EASP-S) and characterizing the relationship between changes in solar-wind velocity and oscillations of the thermobaric field of the troposphere in various regions.

Fig. 1

Figure 1: Fig. 1

with intensification of the zonal form, and then with secondary activation of the meridional type and, finally, during the decline of the s.s.w.—with transformation of the meridional form into the western one. With one maximum of s.s.w., secondary development of high-altitude ridges and troughs is not observed*.

Intrayearly transformations of forms from summer to winter follow the formula: $E_{3+M_1} \rightarrow (E+C)_{3+M_2} \rightarrow C_{M_1+M_2}$ (12). The extension of the high-altitude ridge toward Iceland (form C) in the cold season of the year can be explained by a deficit

Fig. 1. Composite baric maps AT_{500}. **a** —2nd and +1st days relative to the zero benchmark (greatest daily increase of s.s.w.); solid isohypses —geopotential values on the day +1, dotted —for the −2nd day; **b** +1st and +5th days; dotted isohypses —for the +5th day

of air masses in the region of the Icelandic minimum in connection with the redistribution of air masses due to monsoon circulation (3). However, the ratio E/C for this sequence is small. For comparison, an analogous sequence was analyzed, adjacent to the first and differing from it by belonging to the sector of the interplanetary field of the opposite sign. In the second sequence, the emergence of meridional forms C and E after the benchmark date was also observed, but their ratio here is different: 12 cases of E and 18 of C. Assessing the influence of terrestrial and external factors on the different ratio E/C, one may conclude that the action of these factors is, on the whole, the same for both sequences, and the difference between the latter consists in their belonging to sectors of different polarity.

* It is possible, for example, to compare two sequences: 2-10 IV 1963 (one maximum of s.s.w.) and 9-17 X 1963 (two maxima).

The interplanetary field plays an important mediating role in the transfer of the energy of corpuscular streams into the Earth' s magnetosphere during their interaction. The significance of the influence of the sector structure of the field apparently consists in different regimes of flow around the magnetosphere in sectors with opposite polarities. This is indicated by the distribution of the Mach-Alfvén numbers (M_A)* within sectors for quiet [15] and disturbed solar wind. At the boundary of negative and positive sectors a jump in M_A is observed, but on the whole M_A is lower in the positive sector. The forms E and C are characterized by the opposite arrangement of ridges and troughs; therefore the occurrence of form E instead of C after the passage of some sector boundaries makes understandable the inversions of the sign of the correlation found in [1,2].

Using the superposed-epoch method, composite baric maps were constructed for the first sequence: for each day of the sequence, 130 geopotential values were read off on a geographic grid; the criterion for combining them into a statistical ensemble was the identity of the change in the s.s.v. Figure 1 shows two maps: on the first (a) the forms corresponding to the −2nd and +1st days are superposed; on the second (b), those corresponding to the +1st and +5th days. As can be seen in map a), from the −2nd day (zonal form, minimum s.s.v.) to the +1st day there occurs a restructuring of the baric fields and the development of meridional motions (form C)**. Map b) illustrates the strengthening of zonal transport on the +5th day (decline of the s.s.v.) in comparison with the +1st day.

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* $M_A = v/v_A$, where $v_A = H/\sqrt{4\pi\rho}$ is the Alfvén velocity, and H and ρ are, respectively, the field intensity and the plasma density.

** The weak development of ridges and troughs is explained by the fact that the composite maps combine different seasons and varieties of forms, and also by the strengthening of the W-form in the last stage of the circulation epoch of 1949–1964 [12].

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