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GEOEFFECTIVITY OF SOLAR CORONAL HOLES WITH DIFFERENT MAGNETIC FIELD POLARITY

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Abstract

The coronal holes (CH) are sources of high-speed flows of solar wind, and, in its turn, are one of the main sources of geomagnetic disturbances. The coronal holes differ very much one from another and their geoeffectivity varies in a wide range. In this paper we implement a study to answer the question how the coronal holes characterized by different location on the Sun and by their polarity influence the geomagnetic activity. We considere several tens of coronal holes observed in a few recent years, and separate them into groups by the solar latitude and their polarity. A conclusion is made that the trans-equatorial group is the most effective one, and that almost all coronal holes in this group have a negative polarity. Less, but yet sufficiently effective, are the holes of negative polarity at north latitudes and those of positive polarity at south latitudes. The much smaller number of coronal holes of opposite polarity (CH of negative polarity in south hemisphere and CH of positive one in horth hemisphere) are less effective.

1. Introduction

The coronal holes are extended regions in the solar corona where the density and temperature are lower than other places in the corona. The weak, diverging and open magnetic field lines in coronal holes extend radially outward. The high speed path of the solar wind streams out from coronal holes. The low density of the gas makes this parts of the corona appear dark in extreme-ultraviolet and soft X-ray images of the Sun, as if they were a hole in the corona [1, 2].

The investigation of the coronal holes properties and behavior is connected before all with their effects at the Earth. The studies which are related to the coronal holes positions as well as to the flow, polarity and solar wind [3] velocity are really very important. Some models are developed for prediction of the solar wind from coronal holes [4].

The model is based on the position and the magnitude of the solar coronal holes. Some studies are proposed concerning the quantitative analysis of the quadruple component of the magnetic field [5]. By means of this method the magnetic field poles are determined and therefore the coronal holes behavior as well as their appearance and motion. It is assumed that the coronal holes position follows the magnetic field poles motion. All these and also other investigations consider before all the coronal holes, their behavior and structure or the solar wind from them. But these studies do not connect directly the coronal holes with the geophysical activity.

The goal of the present work is to investigate the geoeffectivity of solar coronal holes in dependence on the polarity of the corresponding magnetic fields.

2. Data and methods

The data base for Forbush-effects and interplanetary disturbances developed in IZMIRAN [6] is used by us in order to chose events in which the coronal holes *(CH)* have influence on the Earth’s magnetosphere. 53 events in the period 2011-2012 were chosen, such that a well recognized coronal hole was the source of geoeffectivity in each case. We considered the coronal holes with respect to their polarity and the location on the solar disk. The enumeration and location of the CH we obtained from the site [7], and the polarity was retrieved from data taken from [8].

3. Discussion of the results

We considered 53 events whose sources were coronal holes on Sun. We found 12 coronal holes of negative polarity in the northern solar hemisphere; 16 CH of positive polarity in the southern solar hemisphere; 21 coronal holes crossing the equator (19 of them - of negative polarity, and only 2 – of positive polarity); and 4 untypical coronal holes (3 of them of negative polarity in the southern hemisphere, and one of positive polarity in the north hemisphere).

Table 1. Average characteristics of the geomagnetic activity and of the interplanetary space in studied events

Location	N	S	C	N/S
Polarity	-	+	-/+	+/-
Number	12	16	21	4
Forbush effect	1.01 ± 0.13	0.81 ± 0.09	1.00 ± 0.10	1.15 ± 0.25
Kp_max	3.83 ± 0.35	3.62 ± 0.23	4.27 ± 0.21	3.16 ± 0.35
Ap_max	29.83 ± 6.27	24.63 ± 3.71	35.52 ± 4.38	17.25 ± 3.75
V_{max}	547.3 ± 36.4	524.1 ± 15.0	572.6 ± 22.1	498.5 ± 83.9
Dst_{min}	-34.0 ± 4.6	-21.9 ± 3.3	-32.6 ± 3.8	-15.8 ± 2.4

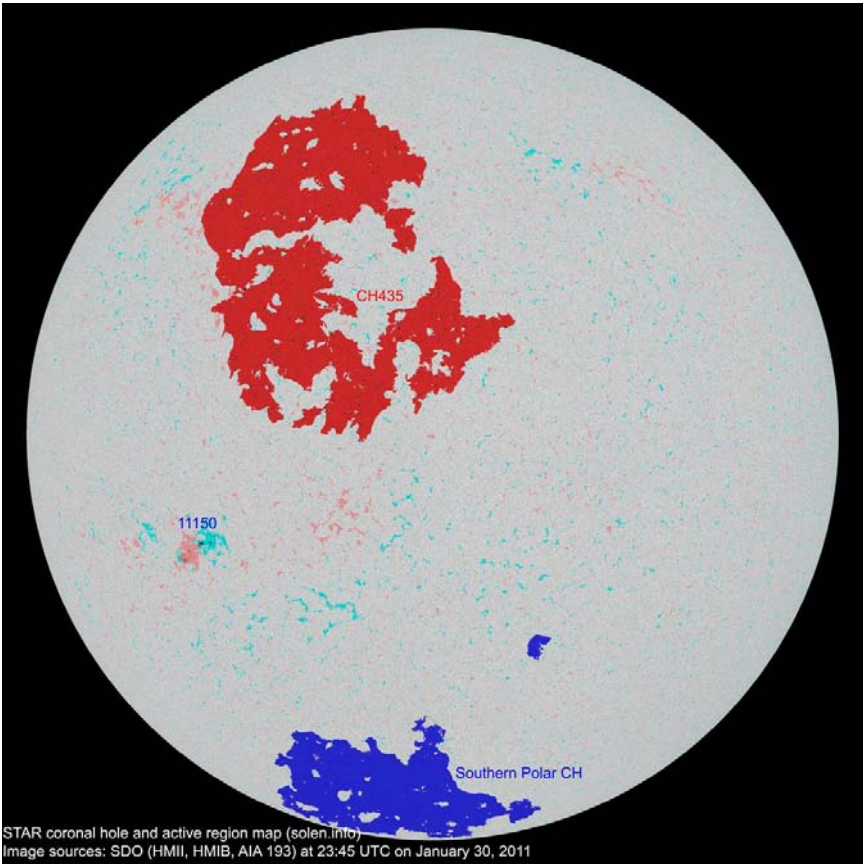

Fig.1. A case of a northern coronal hole of negative polarity of its magnetic field

The coronal hole CH435 demonstrated in Fig.1 passed through the solar central meridian on January 30 - February 1, 2011, and the related geomagnetic effect was observed on the Earth on February 4-8. This hole created a Forbush-effect of magnetude 1.5%, as well as a small geomagnetic storm (Kp-index was 6-, and Dst-index reached –56 nT). The maximal velocity of the solar wind was 647 km/s.

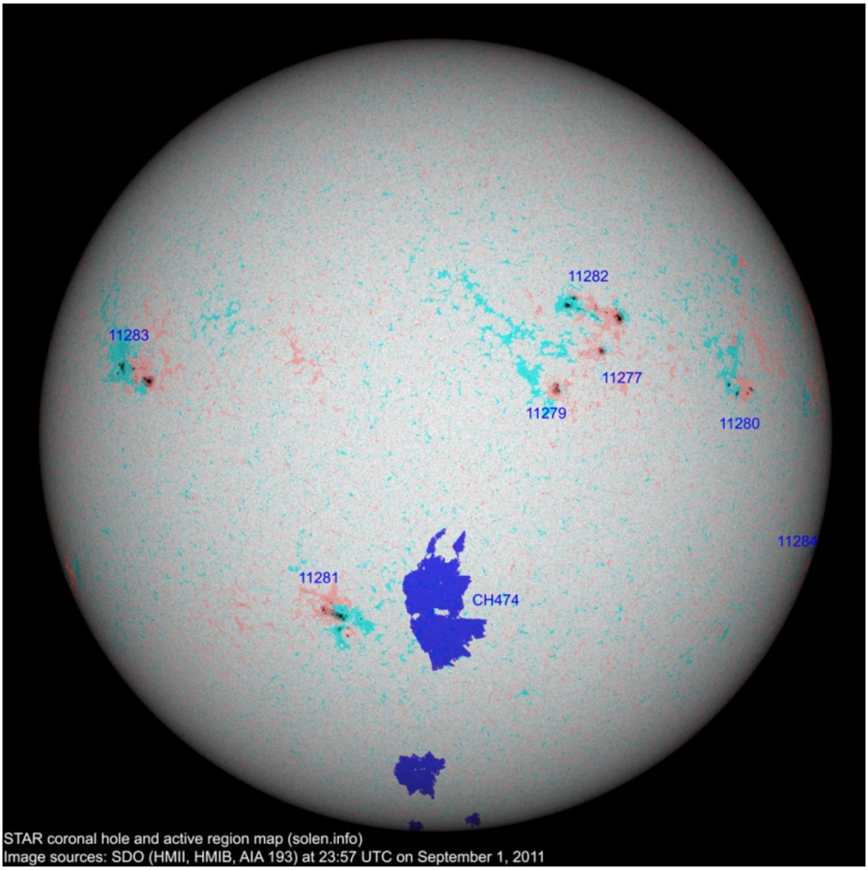

Fig. 2. A case of a southern coronal hole of positive polarity of its magnetic field

The coronal hole CH474, shown in Fig. 2, passed through the solar central meridian on September 1, 2011, and the related geomagnetic effect on the Earth was observed on September 4-8. This hole caused a Forbush-effect of magnetude 0.7%, and was accompanied with a small disturbance of the geomagbnetic field (Kp-index was 3; Dst-index was –20 nT). The maximum velocity of the solar wind was 441 km/s.

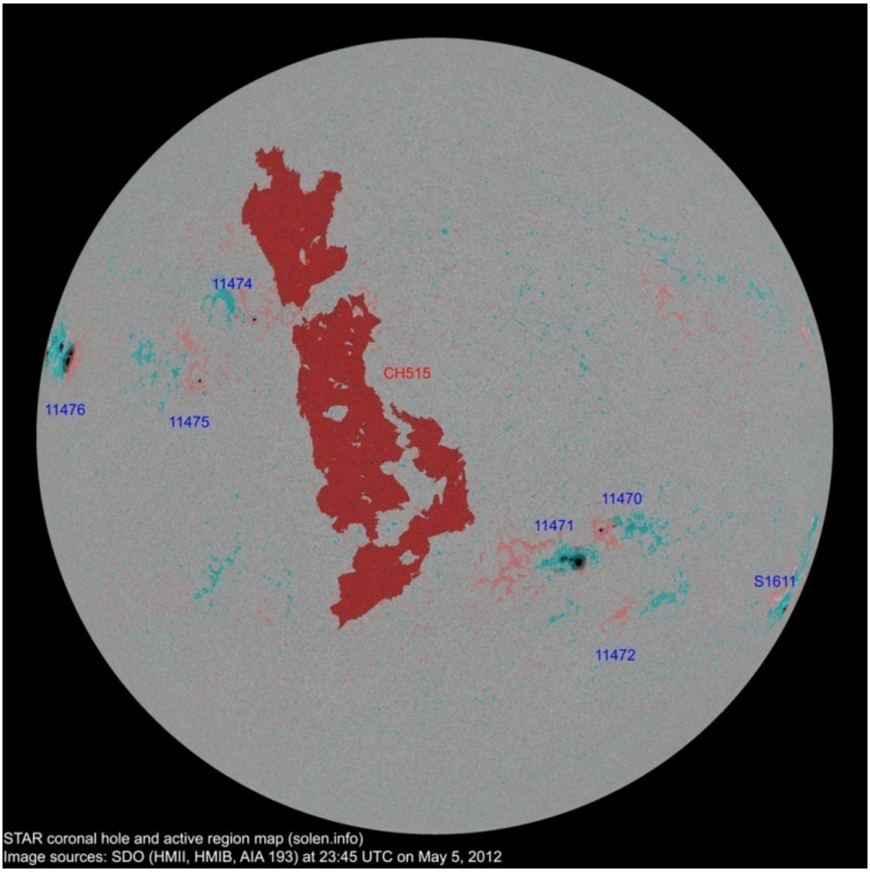

Fig. 3. A case of a trans-equatorial coronal hole of negative polarity of its magnetic field

The coronal hole CH515 demonstrated in Fig. 3 passed through the solar central meridian on May 5-7, 2012, and the related geomagnetic effect was observed on the Earth on May 8-12. This hole created a Forbush-effect of magnetude 1.9%, as well as a small geomagnetic storm (Kp-index was 5-; Dst-index reached –42 nT). The maximum velocity of the solar wind was 638 km/s.

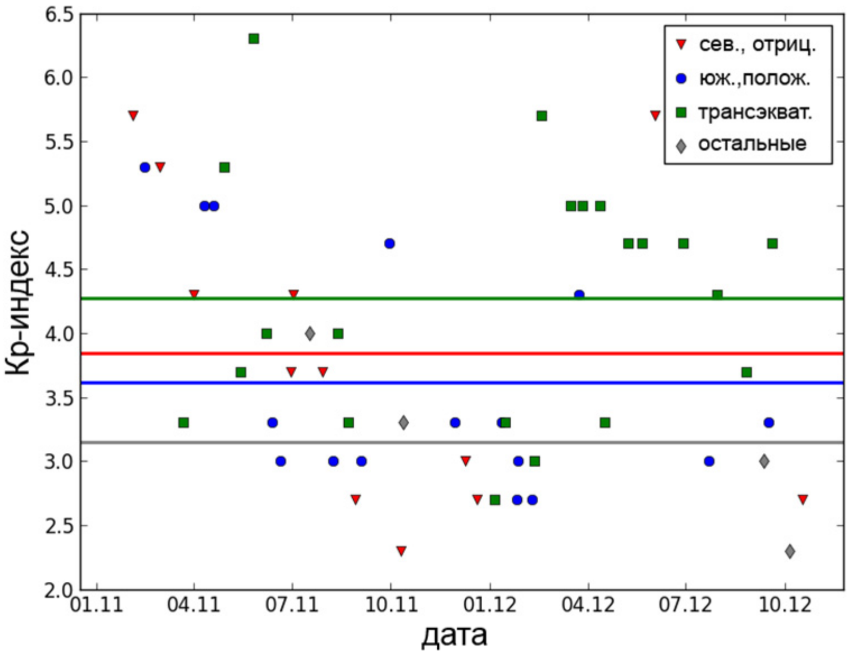

Fig. 4. The average geoeffectivity of the coronal holes in different groups. The horizontal lines correspond to the average value of the Kp index for each group of coronal holes

4. Conclusion

We found that the most geo-effective is the trans-equatorial group, in which almost all coronal wholes are of negative polarity. Our analysis show that less (yet sufficiently) effective are the holes of negative polarity in the northern hemisphere and those of positive polarity in the southern hemisphere. There are very small number of coronal holes of opposite polarity (southern negative, and northern positive); their effectivity is smallest. One has to remember, however, that our study concerns a single solar cycle. We suppose that with the change of sign of the common solar magnetic field opposite results will be obtained.

It is demonstrated, also, that there is no significant difference between the groups considered, with respect to the magnitude of the Forbush-effect. Actually, the intensity of a geomagnetic storm is influenced by the sign of the B_z component of the magnetic field; on the other hand, for the Forbush effect the global interplanetry characteristics, such as the solar wind velocity, the magnitude of the common magnetic field, and dimensions of the disturbance, etc., are important.

The results obtained can not be considered as absolutely correct, since the statistics is rather limited; its further enhancement is needed. Especially, this is related to untypical coronal holes (negative in the southern solar hemisphere, or positive in northern hemisphere). Our goal is to enlarge the statistics and to improve the results in our future works.

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ГЕОЭФФЕКТИВНОСТЬ СОЛНЕЧНЫХ КОРОНАЛЬНЫХ ДЫР С РАЗЛИЧНОЙ ПОЛЯРНОСТЬЮ МАГНИТНОГО ПОЛЯ

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Аннотация

Корональные дыры являются источником высокоскоростных потоков солнечного ветра, которые в свою очередь являются одной из главных причин геомагнитных возмущений. Корональные дыры весьма разнообразны и их геоэффективность меняется в широких

пределах. В данной работе мы попытались исследовать, как влияют на геомагнитную обстановку корональные дыры с различным положением на Солнце и с различной полярностью магнитного поля. Мы рассмотрели несколько десятков корональных дыр, наблюдавшихся в последние годы, и разделили их на группы по гелиошироте и полярности. Наиболее эффективной оказалась трасэкваториальная группа, почти все корональные дыры из этой группы имели отрицательную полярность. Менее, но тоже достаточно эффективными оказались дыры с отрицательной полярностью на севере и с положительной – на юге. Немногочисленные корональные дыры с противоположными полярностями (отрицательные на юге и положительные на севере) были менее эффективными.