Scientific & Educational Centre NEVOD

Features of geophysical manifestations of solar activity in August 2018 according to muon hodoscope URAGAN data

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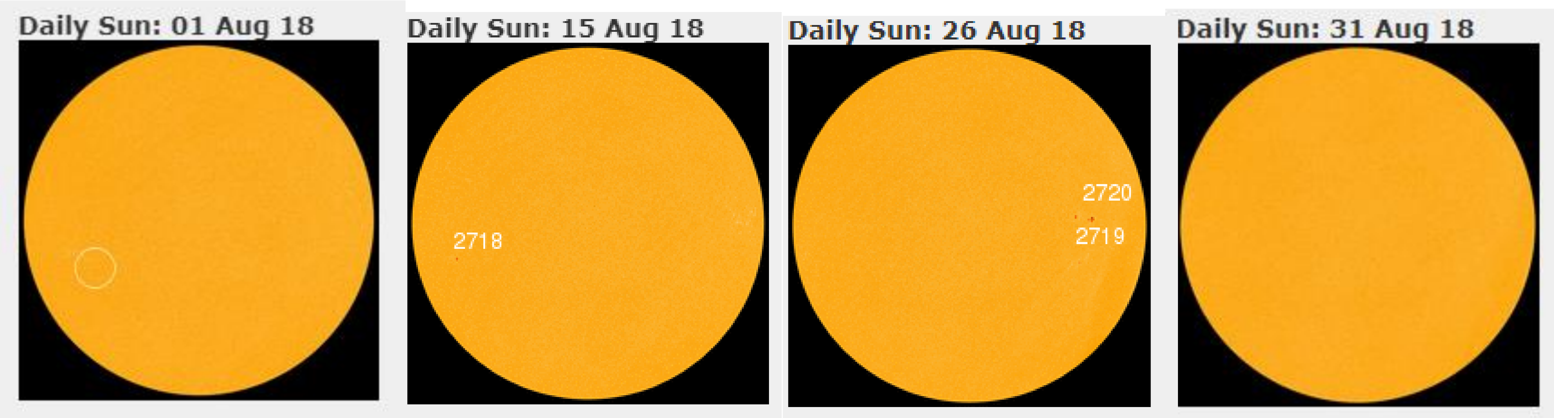
Abstract

24-solar cycle is ending and is characterized by a low solar activity. In summer 2018, the space weather did not portend any features in the geophysical manifestation. The solar disk contained almost no active areas, and the number of spots was close to zero. During August, four coronal holes and some CME of low activity were registered. However, on August, 26 there was a strong magnetic storm (G3). It was characterized by large indexes of geomagnetic activity Dst≈-180 nT and Kp≈8.5. It was found that the disturbance was caused by the eruption of solar filaments on August, 20 from the central part of the Northern region of the disk. The speed of its propagation in the interplanetary magnetic field was as low as 200 – 300 km/s. The eruption of solar filaments caused a geomagnetic storm on 26.08. In this paper, a retrospective analysis of solar wind data (OMNI database) and variations in the flux of cosmic ray muons (data of the ground-based detector URAGAN) was carried out. It was found that the solar wind (B magnetic field, Bz projection, Ey electric field, plasma velocity and temperature) was increased during the stay of the Earth in the regions of the solar wind from the coronal holes. Analysis of the non-stationarity factor Cfn for the time series of muon counting rate N(t) showed that there were always increased Cfn values that were ahead of the fast solar wind by 1 – 4 days. A predictor in the sequence of Cfn values is also found. It was 4 days ahead of the G3 event registration.

Coronal holes

Observation of the solar disk in August 2018 year:

http://spaceweather.com/



A new, unnumbered sunspot is growing at the circled location. Credit: SDO/HMI

New sunspot group AR2718 has broken a string of 11 consecutive spotless days. So far the emerging group is small and quiet--typical of solar minimum sunspots. Credit: SDO/HMI

After bursting onto the scene yesterday with a profusion of large dark cores, reversed polarity sunspot AR2720 is already starting to decay. Credit: SDO/HMI

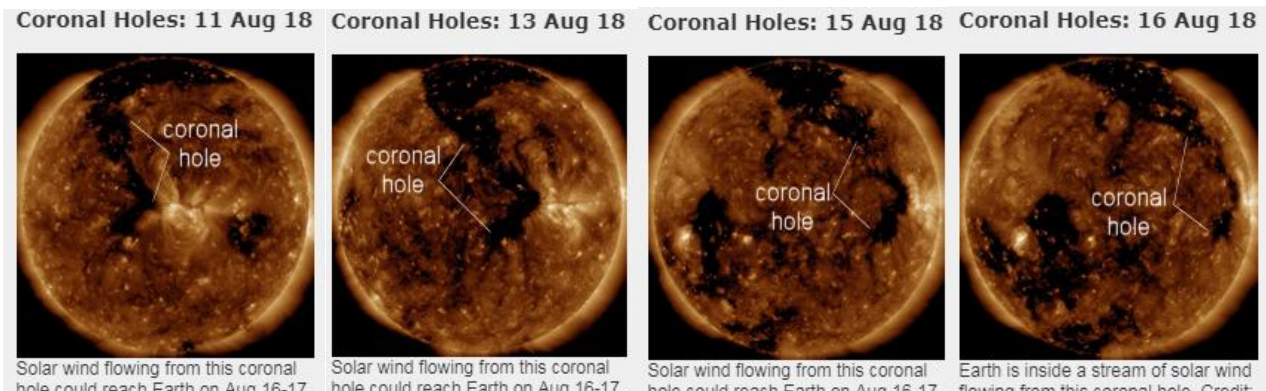
The sun is blank--no sunspots. Credit: SDO/HMI

The sun has been without sunspots for 10 days before of august 2018. A new sunspot is growing in the sun's southeastern quadrant, breaking a string of 10 consecutive spotless days. It is small and still unnumbered. Nevertheless, the emerging dark core merits attention because sunspots are so scarce during this minimum phase of the solar cycle. New sunspot AR2720 is not only large, but also strange. Its magnetic polarity is reversed. The North and South ends of its enormous magnetic field are backwards compared to the norm for sunspots in the current solar cycle, decaying Solar Cycle 24. What does this mean? AR2720 may be the first big sunspot of the next solar cycle, Solar Cycle 25, popping up now in the middle of solar minimum. Solar cycles always mix together at their boundaries. The slow transition between Solar Cycle 24 and Solar Cycle 25 appears to be underway.

Coronal hole (CH) is a region in the sun's atmosphere where magnetic fields open up and allow solar wind to escape. CHs are a primary form of space weather during solar minimum. CHs appear as dark areas in the solar corona in extreme ultraviolet (EUV) and soft x-ray solar images. CH can develop at any time and location on the Sun. CHs are long-lasting sources for high speed solar wind streams. As the high speed stream interacts with the relatively slower ambient solar wind, a compression region forms, known as a co-rotating interaction region (CIR). The CIR will be seen to lead the coronal hole high speed stream (CH HSS). As the CH HSS begins to arrive at Earth, solar wind speed and temperature increase, while particle density begins to decrease. After passage of the CIR and upon transition into the CH HSS flow, the overall IMF strength will normally begin to slowly weaken.

The dynamics of changes in the large trance-equator coronal hole for the period from 11 to 16 August 2018:

http://spaceweather.com/



Solar wind flowing from this coronal hole could reach Earth on Aug.16-17. Credit: SDO/AIA

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Solar wind flowing from this coronal hole could reach Earth on Aug.16-17. Credit: SDO/AIA

Earth is inside a stream of solar wind flowing from this coronal hole. Credit: SDO/AIA

Coronal holes appear as dark areas in the solar corona in extreme ultraviolet (EUV) and soft x-ray solar images. They appear dark because they are cooler, less dense regions than the surrounding plasma and are regions of open, unipolar magnetic fields.

Flicker noise spectroscopy

The main idea is to give information significance to irregularities of analyzed signal - bursts, jumps, etc. In this work we use only part of this method related to calculation of measure of non-stationarity of the analyzed time series. This measure is called a non-stationarity factor (NF), and is calculating the following way. For every point of the time series *N(t)* we calculate two values *Q(k)* and *P(k)*. Actually they are structure functions, calculated inside a time window of length *T* and integrated over all scales *t*:

$$Q_k = \frac{1}{\alpha T^2}\int_0^{\alpha T} d\tau \int_{t_k}^{t_k+T} \left[N(t)-N(t+\tau)\right]^2 dt, \quad P_k = \frac{1}{\alpha T^2}\int_0^{\alpha T} d\tau \int_{t_k}^{t_k+T-\Delta T} \left[N(t)-N(t+\tau)\right]^2 dt,$$

where *t* is the time lag parameter ($0<t<T/2$). Then we get value of non-stationarity factor *C(tk)* using formula:

$$C(t_k) = 2\cdot\frac{Q_k-P_k}{Q_k+P_k}\Big/\frac{\Delta T}{T} = \frac{\Delta Q}{Q}\Big/\frac{\Delta T}{T}.$$

Value *T* is the parameter of this method. It is associated with a characteristic time of restructuring the analyzed signal at all spatial scales. This technique allows to see hidden variations of the CR flux by peaks on the plot of NF.

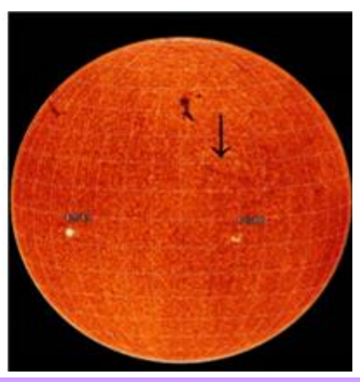
Geoeffective effect of coronal holes on the Earth's magnetic field during August 2018

Star coronal hole tag	Location	Earth facing position date interval, August	Date interval, August 2018: Geomagnetic disturbance	Date interval, August 2018: Geomagnetic index, AE > 500, nT	Geomagnetic index Kp: Kp dominant/ Kp max/ Ap max	Geomagnetic index (max) Dst, nT
CH877	TE	01	none	none	-/-/-	-
CH878	N	03	07	03	2/3/15	-
CH879	TE	07-08	11	07	2/4/27	-
CH880	NE	11-13	15-17	11	3/4/24	-
CH881	TE	17-20	20-22	15-21	3/4/22	-
CH882	NE	27-28	none	24-28	-/-/-	**-174**

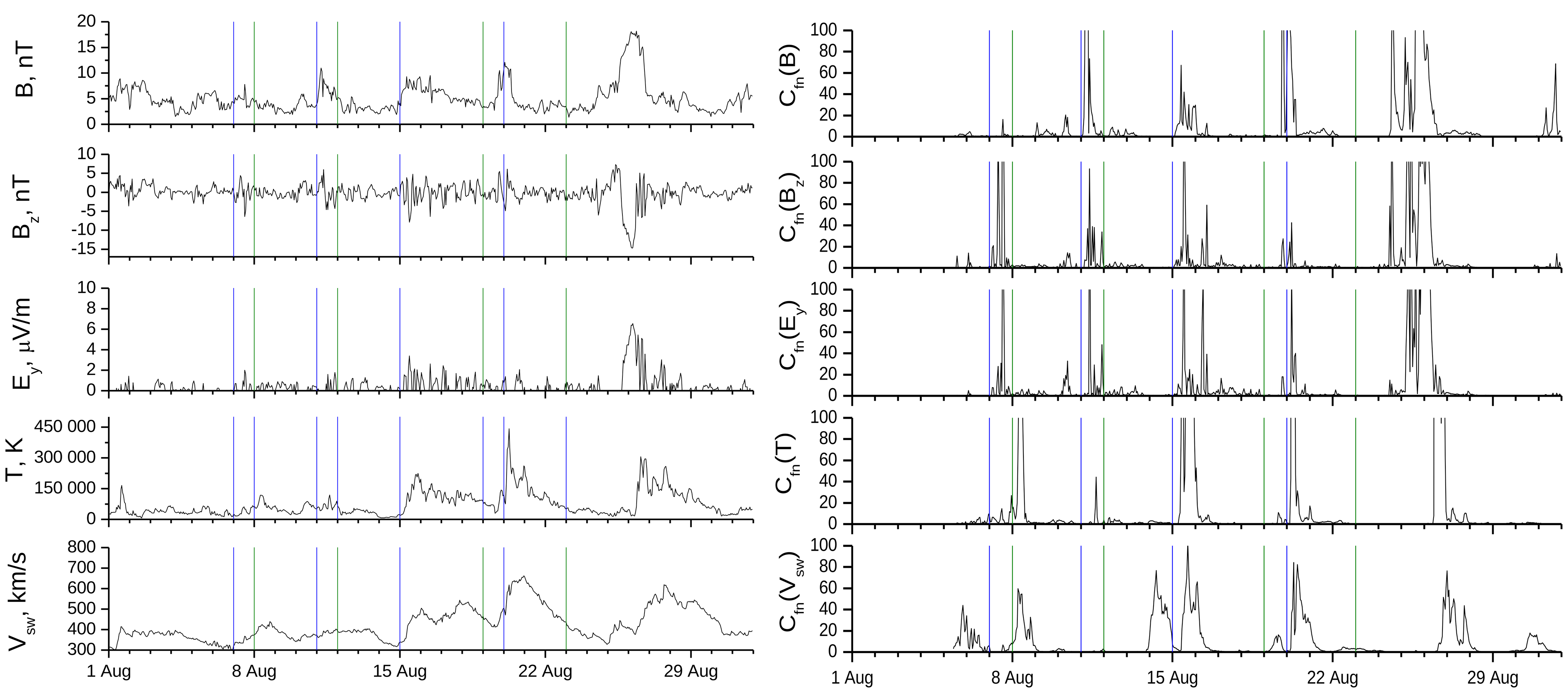
The values of the Kp and Dst indices were almost at the background level. The disturbance of the Dst-index is due to the CME eruption.

Information about CME

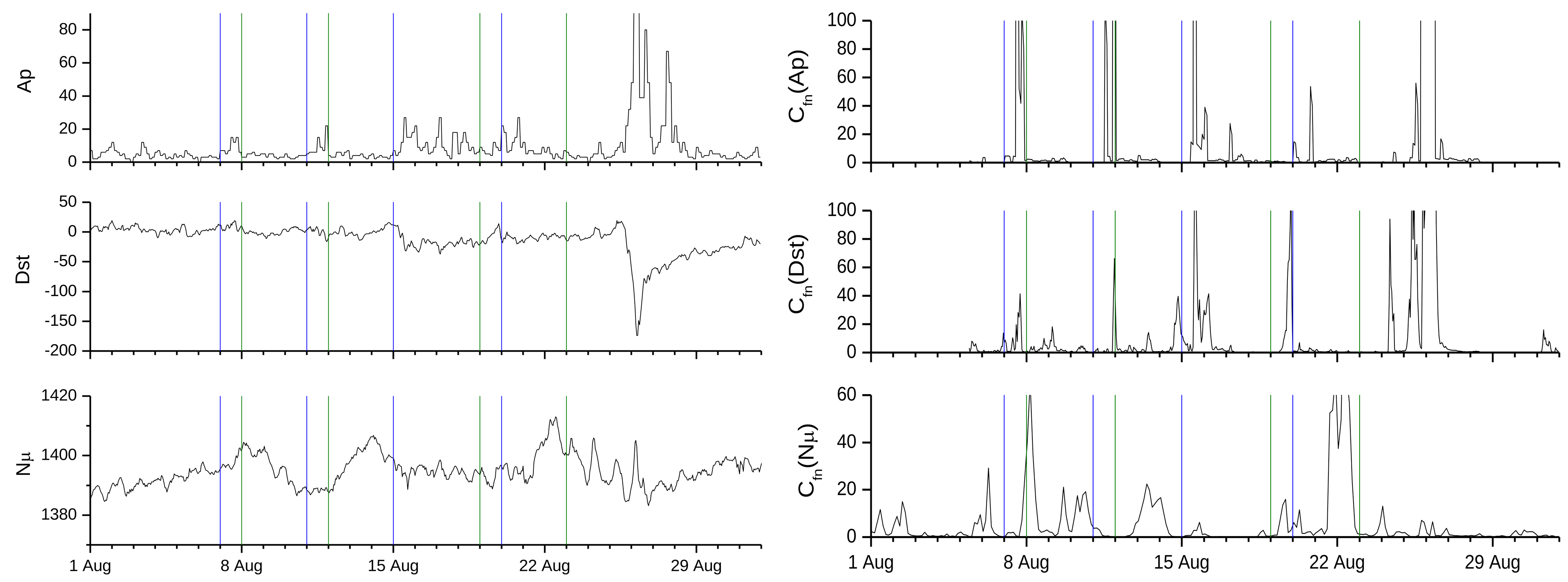
Start: 20.08.2018 21:24 UT
VCME: 200 – 400 km/s
Geomagnetic disturbance:
25 – 26 august (12:00 – 12:00 UT)
Geomagnetic index:
Kp = 7.7 (G3), Dst = -174 nT



Analysis of the dynamics of the solar wind



Analysis of the dynamics of cosmic-ray muon flux and disturbances of the Earth's magnetic field



Conclusion

1. For the first time, we have applied a method of flicker-noise spectroscopy to study variations in the flux of cosmic rays and various parameters of the solar wind during the eruption of a fast solar wind from coronal holes.

2. The nonstationarity factor calculation is free of the traditional model analyzing functions used in Fourier and wavelet analysis.

3. The nonstationarity factor is an indicator of signals hidden in the statistical noise of the muon flux. It reflects well the time moments of restructuring for various types of plasma fluxes. This factor can be used for estimating the predictors of geoeffective disturbances of the solar wind. The FNS method can be used to investigate a wide class of phenomena in the field of solar-terrestrial physics.

Acknowledgments

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