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Criteria for early detection of geomagnetic disturbances caused by coronal holes during periods of low Solar activity based on muon flux variations

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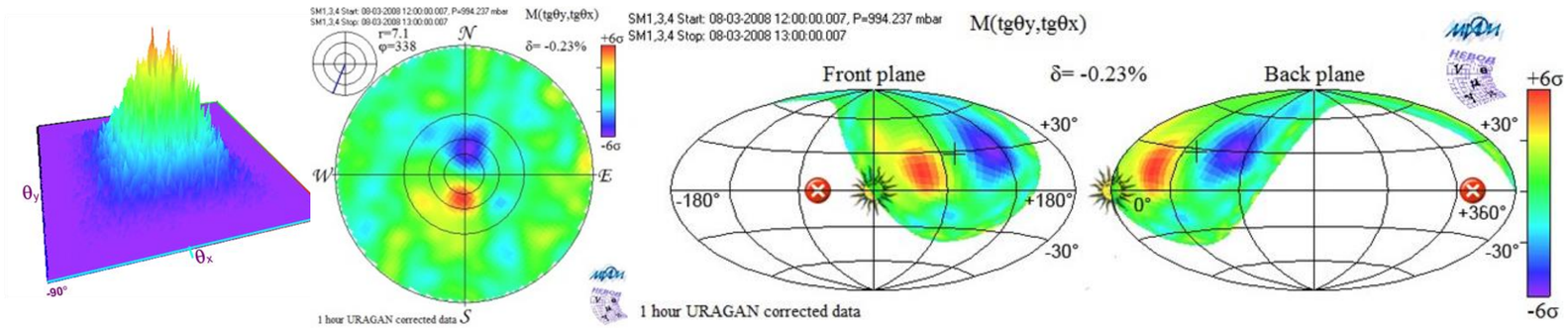
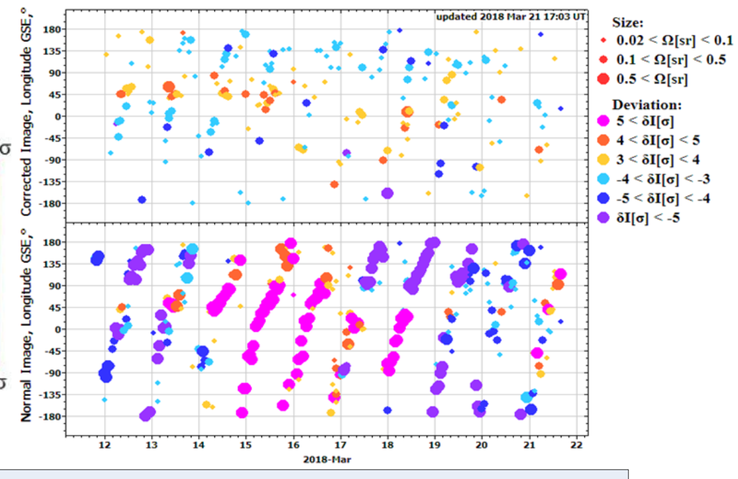
MUON HODOSCOPE URAGAN

Muon hodoscope (MH) URAGAN is a large-aperture coordinate-tracking detector capable to detect muons in a wide range of zenith angles (0°-80°). It is used to study characteristics of the muon flux spatial-angular variations. Hodoscope consists of four supermodules (SMs) with a total area of ~ 46 m^2 and has high spatial (~ 1 cm) and angular (~ 1°) accuracies. SM consists of eight layers of streamer tubes equipped with a two-coordinate system of external readout strips. Each registered muon with reconstructed arrival direction is recorded in a two-dimensional angular matrix which represents an image of the upper hemisphere in the flux of muons with an exposition of 1 minute.

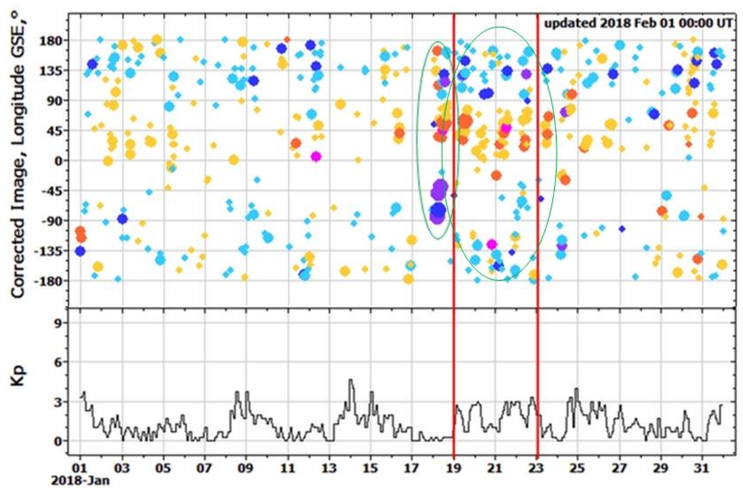




ANALYSIS OF VARIATIONS IN THE FLUX OF COSMIC RAYS

Coronal holes generate high speed solar wind. This wind is the cause of magnetic storms on the Earth during years of low solar activity. Also the high speed solar wind creates a disturbance in the interplanetary magnetic field. The disturbance may mirror hitting it cosmic rays in the direction of the Earth. As a result, on the Earth's surface, it is possible to observe an increase in the flux of cosmic rays before the arrival of the disturbance.

[https://omniweb.gsfc.nasa.gov]
[https://www.solen.info/solar/coronal_holes.html]
[http://ipg.geospace.ru/]



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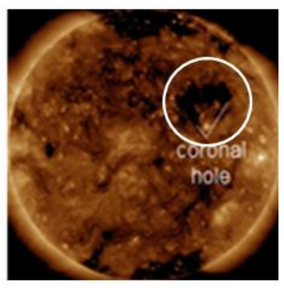
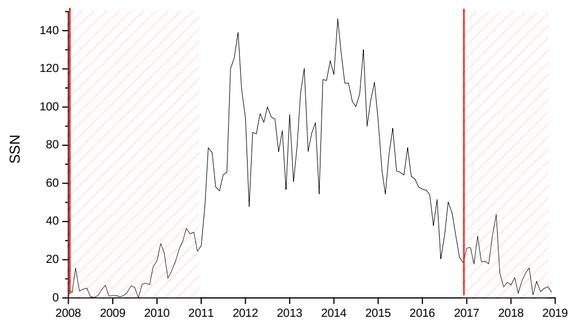
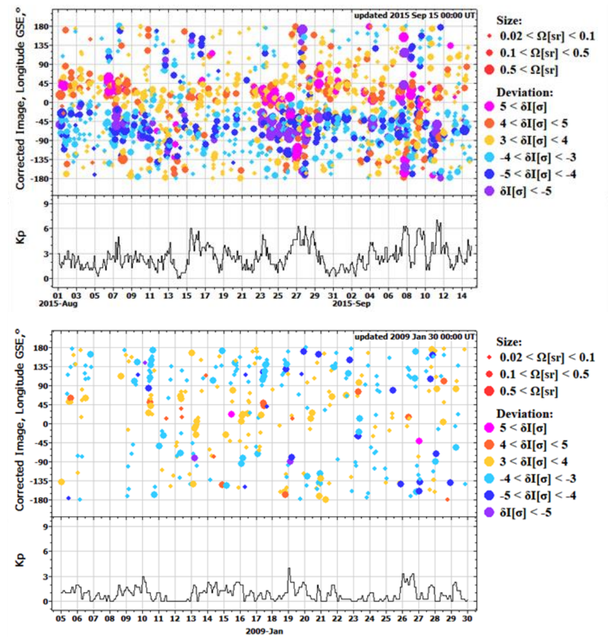


The investigated two periods

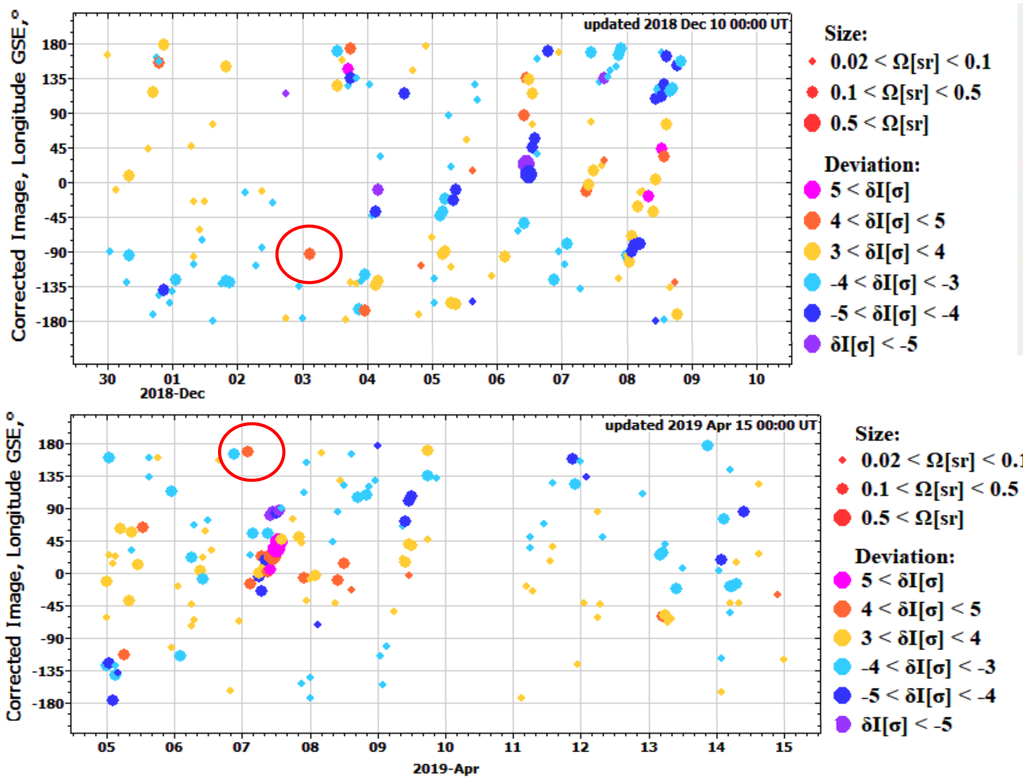




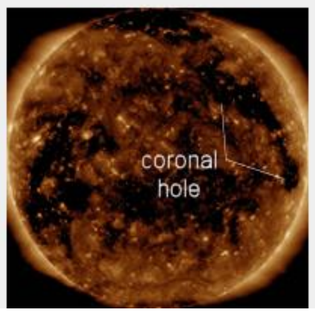
The wave incident from the disturbance reflects CR and, as a result, an area of increased CR intensity is visible on the Earth.

GSE-maps in the periods of minimum (January, 2009) and maximum (August-September, 2015) of solar activity

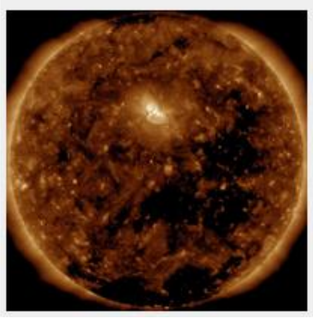
Examples of events in which an early rise in the flux of cosmic rays was detected

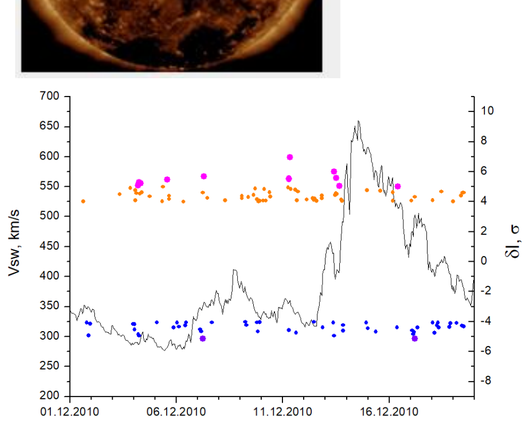


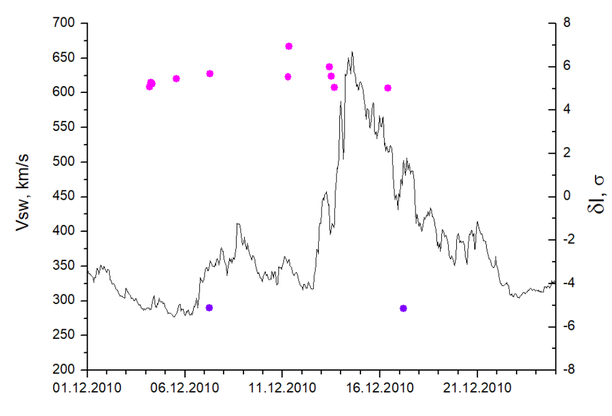
Coronal Holes: 02 Dec 18



Coronal Holes: 04 Apr 19







Conditions:

1. Area size

0.1 < Ω[sr] < 0.5
0.5 < Ω[sr]

2. Deviation within the area

5 < δI[σ]
4 < δI[σ] < 5

-5 < δI[σ] < -4
δI[σ] < -5

For the considered geoeffective coronal holes, the hodoscope response was detected earlier than the recorded disturbance of the Earth's magnetosphere (Kp ≥ 4) by an average of 7 ± 1 hours.

In 61 out of 112 MH responses to the considered coronal holes, a region of increased muon flux was observed.

CONCLUSION

1. We examined 112 magnetic storms during the Sun's low activity. These storms were caused by coronal holes in the Sun.
2. In the study, we used the data of the Muon Hodoscope URAGAN, namely the GSE-maps.
3. We noticed that in 54% ± 4% of the cases, the main hodoscope response is preceded by an area with an increased flux of cosmic rays intensity.
4. We consider the appearance of this area as a criteria for early detection of geomagnetic disturbances.

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