

REPORT of ANEMOS/NKUA TEAM

An Extreme Geomagnetic storm (G5) on 10-11 May 2024

An unusual and historic geomagnetic storm in almost 20 years took place on May 10-13, 2024. Several CMEs hit Earth's magnetic field, causing geomagnetic storm of extreme storm level (G5) in the middle-latitude stations and a GLE event in the polar stations during the recovery of a large Forbush Decrease.

1. Solar Activity

On May 10-13, 2024, an extreme geomagnetic storm (G5) was occurred near the maximum of the solar cycle 25. This storm was noticed due to the effects of multiple CMEs that were observed on the Sun and are analyzed below:

May 08: A full halo CME was observed on May 08 at 05:36 UT ([CME Scoreboard \(nasa.gov\)](#)). This CME was expected to reach Earth on May 10 between 14:59 UT and 23:52 UT according to EAM predictions (Paouris and Mavromichalaki, 2017a; 2017b).

May 08: Another full halo CME was observed on May 08 at 12:24 UT from AR3664 following a long-duration M8.6 class solar flare. This CME was expected to reach Earth on May 11 between 02:35 UT and 08:11 UT according to EAM predictions.

May 09: A halo CME was observed on May 09 at 09:24 UT after the X2.3 class solar flare. This CME was expected to reach Earth between May 10 at 23:16 UT and May 11 at 19:45 UT according to EAM predictions.

May 10: The X3.9 class solar flare associated with another CME which was observed on May 10 at 07:12 UT. This CME was expected to reach Earth on May 12 between 08:50 UT and 22:46 UT according to EAM predictions.

May 11: Another bright partial halo CME was observed on May 11 at 01:36 UT associated with a X5.8 class solar flare. This CME was expected to reach Earth between May 12 at 18:00 UT and May 13 at 13:15 UT according to EAM predictions.

During this period from May 8, 2024 until May 13, 2024 several M- class solar flares and 9 X- class ones were occurred (Figure 1). The most energetic one was the X5.8 flare (Figure 2) on May 11, 2024 at 01:23 UT (peak time) from the AR3664 ([www.SolarMonitor.org](#)). A radio blackout of level R3 was also observed.

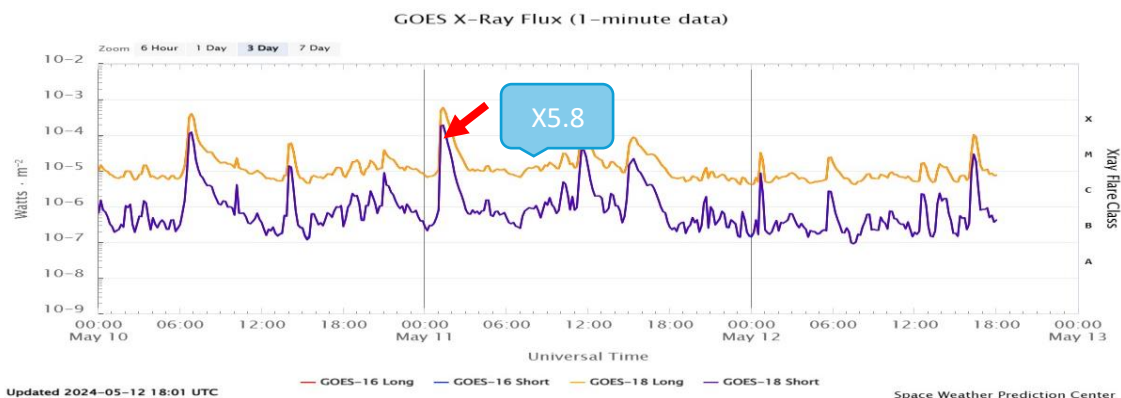


Figure 1: The X-class solar flares as detected by the GOES satellites.

(<http://www.swpc.noaa.gov/products/goes-x-ray-flux>)

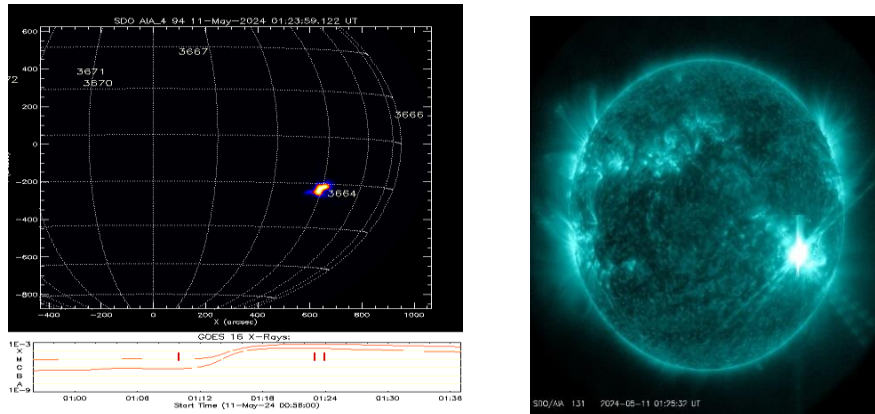


Figure 2: The X5.8 solar flare of May 11, 2024 at 01:23 UT peak time (from <https://www.lmsal.com/solarsoft> and <http://sdo.gsfc.nasa.gov/data/aiahmi/>).

2. Solar Energetic Particle Events

GOES Proton Flux for particles with energies above 10 MeV exceed the SWPC 10 MeV warning threshold on May 10 at 14:10 UT. A solar radiation storm reached the level of S2 (Figure 3).

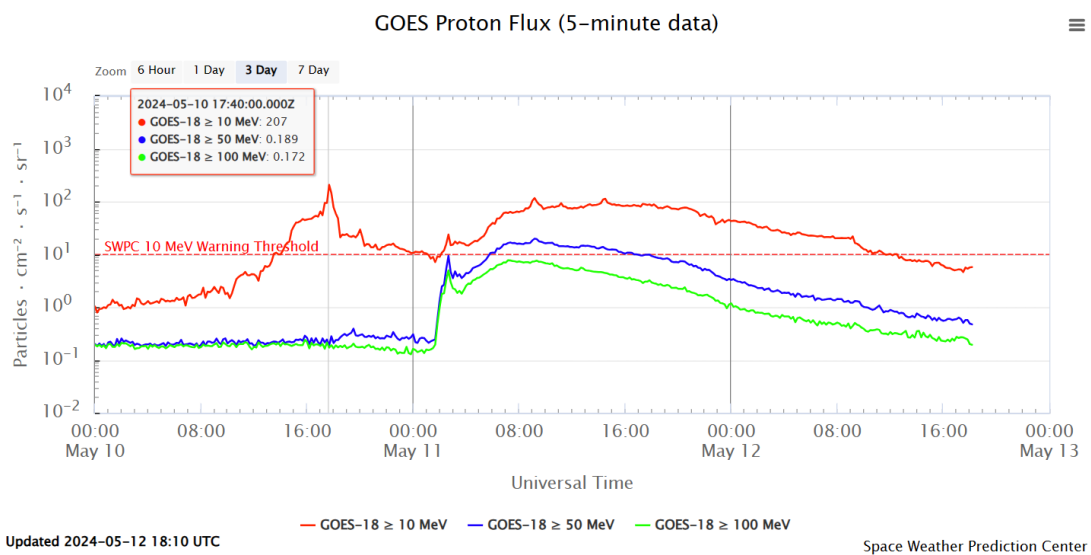


Figure 3: Alert signal issued by Space Weather Prediction Center (SWPC) of NOAA.

3. Interplanetary conditions

Due to the effects of the geomagnetic storm the solar wind speed reached a peak of about 989 Km/s on May 12, 2024 at 00:50 UT as detected from ACE. The arrival signature was characterized by sharp decrease of the vertical component of IMF Bz reaching -48nT on May 11, 2024 at 00:45 UT (Figure 4). (<http://www.swpc.noaa.gov/products/real-time-solar-wind>).

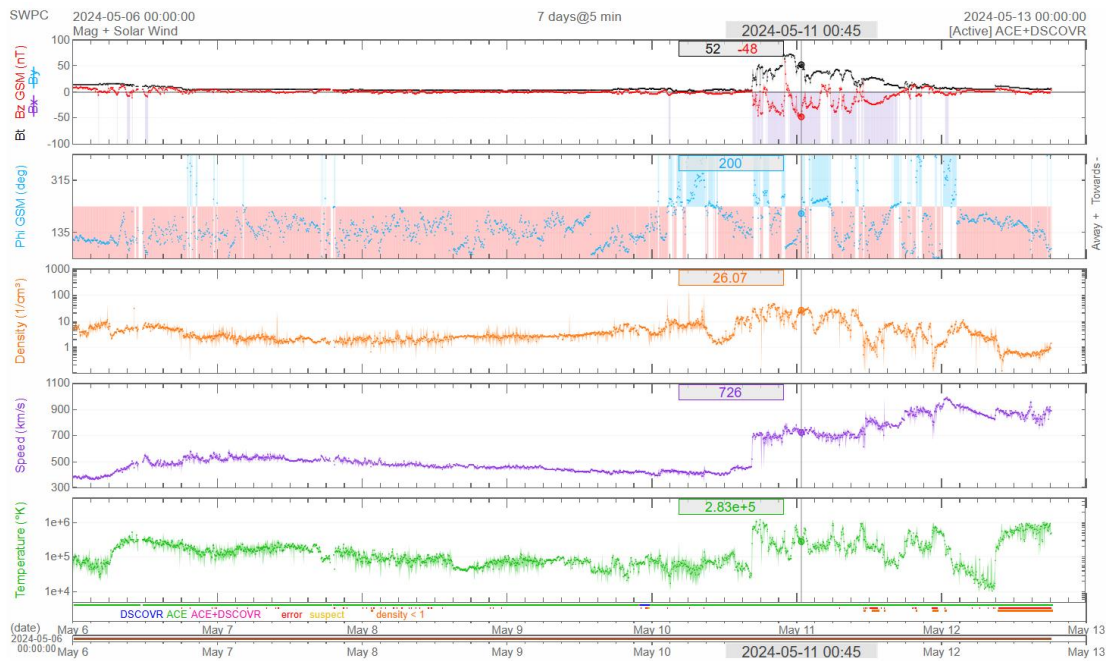


Figure 4: Solar wind speed and vertical component of IMF Bz from DSCOVR spacecraft.

4. Geophysical Activity

The arrival of the above CMEs was forecasted and reported from Athens Space Weather Forecasting Center ([ASWFC \(uoa.gr\)](http://aswfc.uoa.gr)).

Due to the effects of the CMEs produced on May 8-9, 2024 the daily value of Ap index reached the max value **274** on May 11, 2024 and the geomagnetic storm reached the level G5 (extreme storm) with the corresponding Kp index equal to 9 (Figure 5). Also, according to GFZ the actual value of ap_{max} equal **400** on May 11, 2024 at 00:00 UT (http://www-app3.gfz-potsdam.de/kp_index/qlyymm.html).

During the study period of the storm the Dst index reached the minimum value -412 nT on May 11, 2024 at 03:00 UT (**Figure 6**) ([Real-time \(Quicklook\) Dst Index Monthly Plot and Table \(kyoto-u.ac.jp\)](#)).

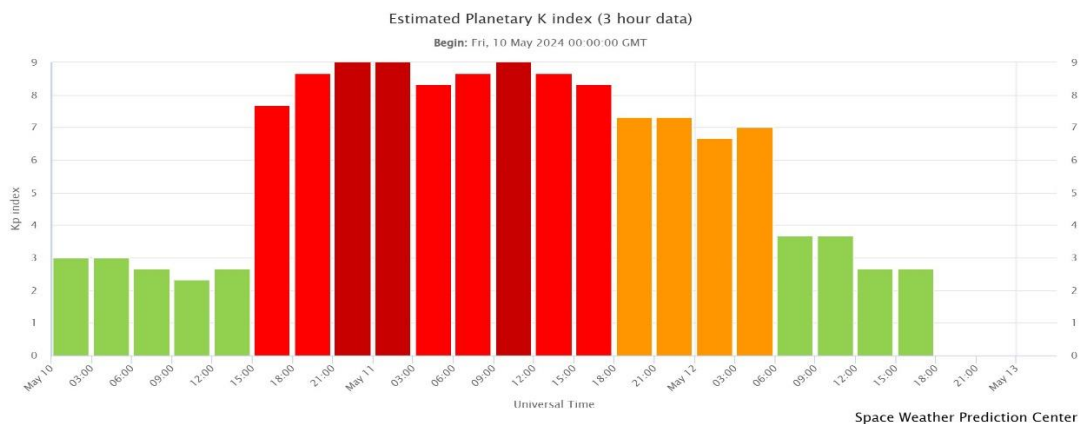


Figure 5: Kp index values for the period May 10-13, 2024.

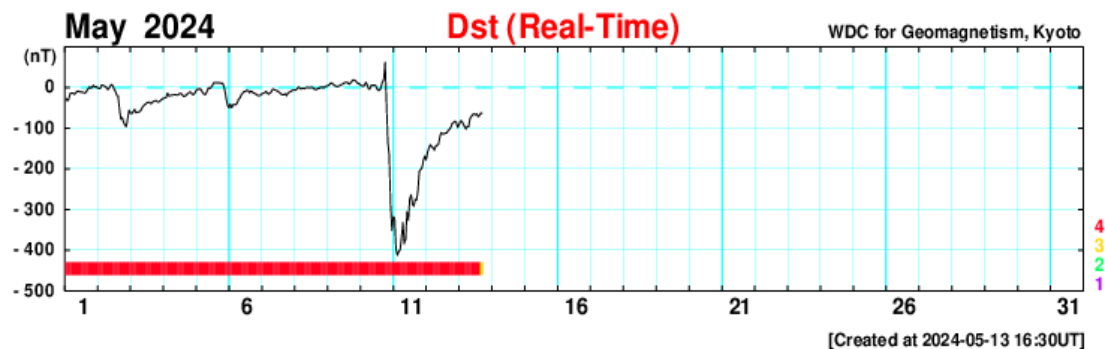


Figure 6: The variation of Dst index during the study period.

[\(Real-time \(Quicklook\) Dst Index Monthly Plot and Table \(kyoto-u.ac.jp\)\)](https://www.kyoto-u.ac.jp/~wdc/geomag/realtime/dst/)

5. Cosmic rays

The results of the geomagnetic storm were spotted on the cosmic ray intensity. A **Forbush decrease started on May 10, 2024** as a result of the arrivals of CMEs. The cosmic ray intensity as recorded at the Oulu neutron monitor station (cut-off rigidity 0.8 GV) is illustrated in Figure 7.

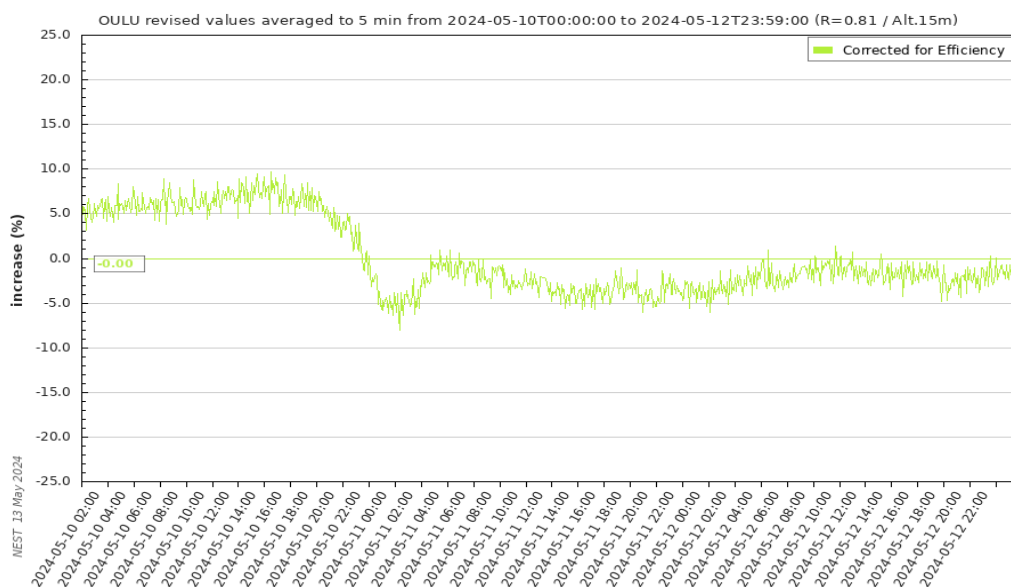


Figure 7: The counting rate of the Oulu Neutron Monitor Station on May 10-12, 2024 (nmdb.eu/nest/)

6. The ap Prediction tool

The ap Prediction tool (ESA G-ESC G.171) estimated the time arrival of the CMEs to the Earth on May 10-13, 2024, and the ap index fluctuations (Figure 8).

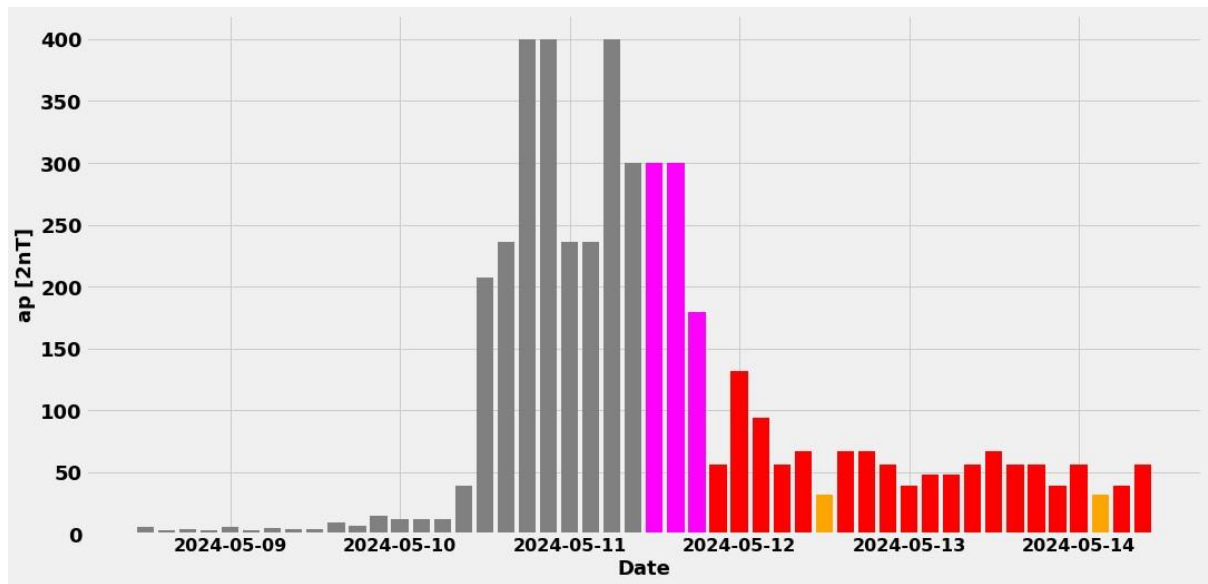


Figure 8: Colored scaled plot of ap values showing in grey color past 72 hours from May 08, 2024 to May 11, 2024 (actual data provided by GFZ) and the forecasted values for the next 72 hours from May 11, 2024 to May 14, 2024.

The algorithm of the tool calculated the arrival time of the CME using the Effective Acceleration Model – EAM. Also, linear regression machine learning algorithms are used for the estimation of the maximum ap value using as dependable variable the angular width and the median velocity (Stassinakis et al., 2023).

During the geomagnetic storm the actual value of ap_{max} was equal to 400 nT which correspond to Kp value equal to 9⁰ according to GFZ (http://www-app3.gfz-potsdam.de/kp_index/qlyymm.html) (Figure 8).

CMEs are explosions of plasma and magnetic fields from the sun’s corona. They cause geomagnetic storms when they are directed at Earth. **Geomagnetic storms can impact infrastructure in near-Earth orbit and on Earth’s surface**, potentially disrupting communications, the electric power grid, navigation, radio and satellite operations. [SWPC has notified the operators of these systems](#) so they can take protective action.

References:

- E. Paouris and H. Mavromichalaki: ‘Effective Acceleration Model for the arrival time of interplanetary shocks driven by coronal mass ejections’, Solar Physics, 292, 180, 2017a, doi: 10.1007/s11207-017-1212-2.
- E. Paouris and H. Mavromichalaki: ‘Interplanetary coronal mass ejections resulting from Earth-Directed CMEs Using SOHO and ACE Combined Data During Solar Cycle 23’ Solar Physics, 292, 30, 2017b, doi: 10.1007/s11207-017-1050-2.
- A. Stassinakis, M. Livada, M. Gerontidou, A. Tezari, H. Mavromichalaki, E. Paouris, P. Makrantonis: ‘Forecast of the Geomagnetic Index ap during CME events’, European Space Weather Week, 2023.