ESA SPACE WEATHER NETWORK SERVICE

REPORT of ANEMOS/NKUA TEAM

Geomagnetic conditions Service Center -G.171 Product

"Automated Process of the ap Prediction tool"

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**The Severe Geomagnetic Storm (G4) on October 10-11, 2024**

## 1. Solar Activity

During the maximum of the solar cycle 25 on October 10-11, 2024, a severe geomagnetic storm (G4) was occurred. This storm was noticed due to the effects of the CME that was observed on the Sun on October 09, 2024 at 02:12 UT (CME Scoreboard; nasa.gov), associated with an X1.8 class flare from the active region AR3848 peaking on October 09 at 01:56 UT (Figure 1). This CME was expected to reach Earth between October 10 at 10:50 UT and October 11 at 09:06 UT according to Effective Acceleration Model (EAM) prediction of National and Kapodistrian University of Athens (Paouris and Mavromichalaki, 2017a; 2017b). The actual shock arrival time of the above CME was noticed on October 10, 2024 at 14:46 UT and producing a geomagnetic storm of level G4.

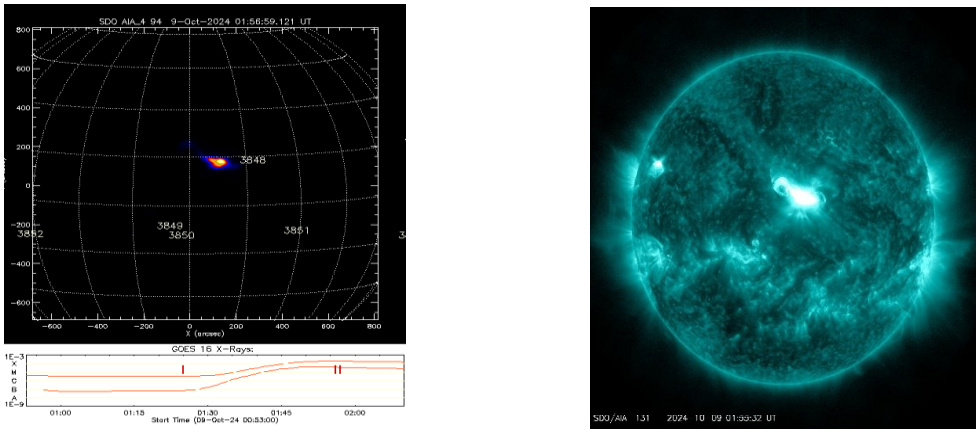


**Figure 1:** The X1.8 solar flare on October 09 at 01:56 UT peak time (from https://www.lmsal.com/solarsoft and http://sdo.gsfc.nasa.gov/data/aiahmi/).

## 2. Solar Energetic Particle Events

GOES Proton Flux for particles with energies above 10 MeV exceeded the SWPC 10 MeV warning threshold on October 09 at 05:00 UT. A solar radiation storm of level S3 was observed. The SPE was ended on October 11 at 03:15 UT (Figure 2).

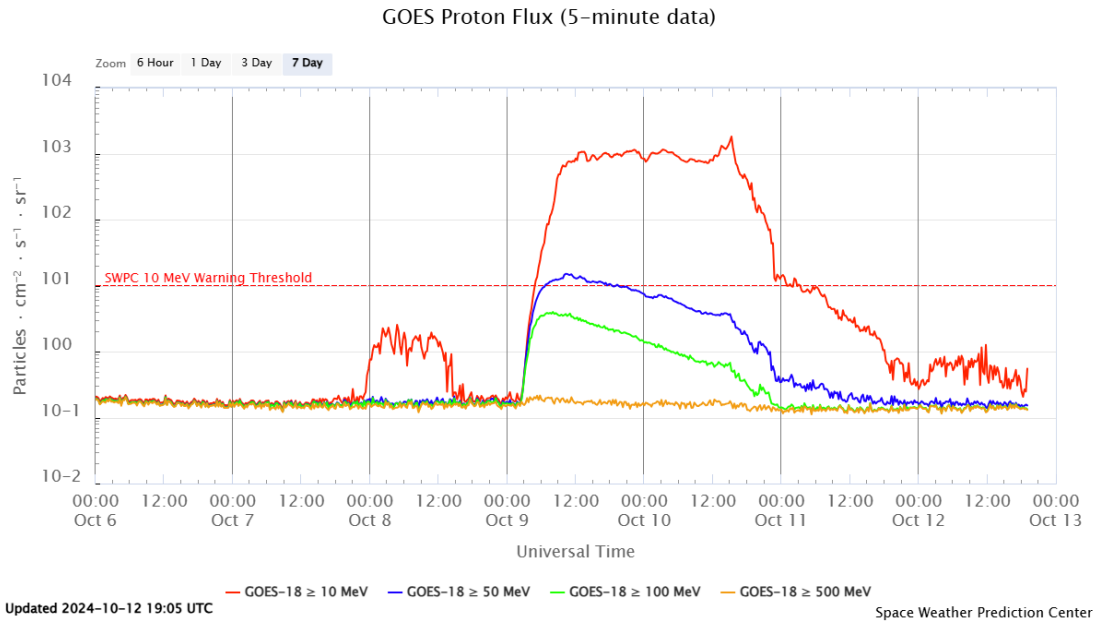


**Figure 2:** Alert signal issued by Space Weather Prediction Center (SWPC) of NOAA. (http://www.swpc.noaa.gov/products/goes-proton-flux)

## 3. Interplanetary conditions

Due to the effects of the CME the solar wind speed reached a peak of about 786 Km/s on October 10, 2024 at 22:10 UT as detected from ACE. The arrival signature was characterized by a sharp decrease of the vertical component of IMF Bz reaching -42 nT on October 10, 2024 at 22:00 UT (Figure 3).


**Figure 3:** Solar wind speed and vertical component of IMF Bz from DSCOVR spacecraft. (http://www.swpc.noaa.gov/products/real-time-solar-wind)

## 4. Geophysical Activity

The arrival of the above CMEs was forecasted and reported from Athens Space Weather Forecasting Center (ASWFC (uoa.gr)) (Figure 4).

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Product: Daily Forecast of Geomagnetic Activity
Issued: 2024 October 10 08:27UTC
Prepared by the Athens Space Weather Forecasting Center
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I. Solar activity
--Current Status
Solar Flux (10.7cm) measured on 09.10.2024 at 23:00 UTC was 220 sfu.
The background X-Ray flux is at the class C4.5 level.
Two X-class flares and two M-class solar flares were produced on October 09 and
the biggest event was an X1.8 flare.
AR3848 erupted on October 09 at 01:56 UT peak time producing a X1.8 class solar
flare and a radio blackout of category R3.
No obviously Earth directed CMEs were observed in available LASCO imagery on
October 05-06.
---CME arrival forecast
A CME was observed on October 07 at 20:48 UT. This CME is expected to reach Earth
between on October 10 at 23:32 UT and on October 11 at 12:08 UT according to EAM
predictions.
Another CME was observed on October 09 at 02:12 UT, associated with the X1.8
class flare. This CME could reach Earth between on October 10 at 10:50 UT and on
October 11 at 09:06 UT according to EAM predictions.

II. Solar Energetic Particle Events
GOES Proton Flux for particles with energies above 10 MeV exceed the SWPC 10 MeV
warning threshold on October 09 at 05:00. A solar radiation storm of level S3 was
also observed.

III. Interplanetary and Geomagnetic conditions
The solar wind speed measured by ACE satellite reached the max value 463 Km/s on
October 09 at 13:10 UT during the last 24 hours.
The solar wind speed from STEREO A was detected 600 Km/s during the last 24
hours.
The vertical component of IMF Bz reached the max value -6 nT on October 09 at
10:05 UT during the last 24 hours.
The geomagnetic field was at unsettled to active levels during the last 24 hours.
The Kp index now is at unsettled levels with Kp=3.

IV. 3-day Geomagnetic Activity Forecast
The geomagnetic field is expected to be at quiet to severe storm (G4) levels on
October 10, at active to severe storm (G4) levels on October 11 due to the effect
of CMEs and at quiet to minor storm (G1) levels on October 12.
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| Date | Ap index forecast | Geomagnetic Activity level |
|---|---|---|
| 10.10.2024 | 100 | Quiet to Severe Storm (G4) |
| 11.10.2024 | 120 | Active to Severe Storm (G4) |
| 12.10.2024 | 30 | Quiet to Minor storm (G1) |

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Athens Neutron Monitor Station A.NE.MO.S
Tel.: +30 210 727 6901
email: spaceweather@phys.uoa.gr
URL: http://spaceweather.phys.uoa.gr
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Due to the arrival of the CME on October 10, 2024 the daily value of Ap index was equal to 97 with the corresponding Kp index equal to $9^-$ (Figure 5). During the study period of the storm, the Dst index reached the minimum value – 335 nT on October 11, 2024 at 02:00 UT (Figure 6).

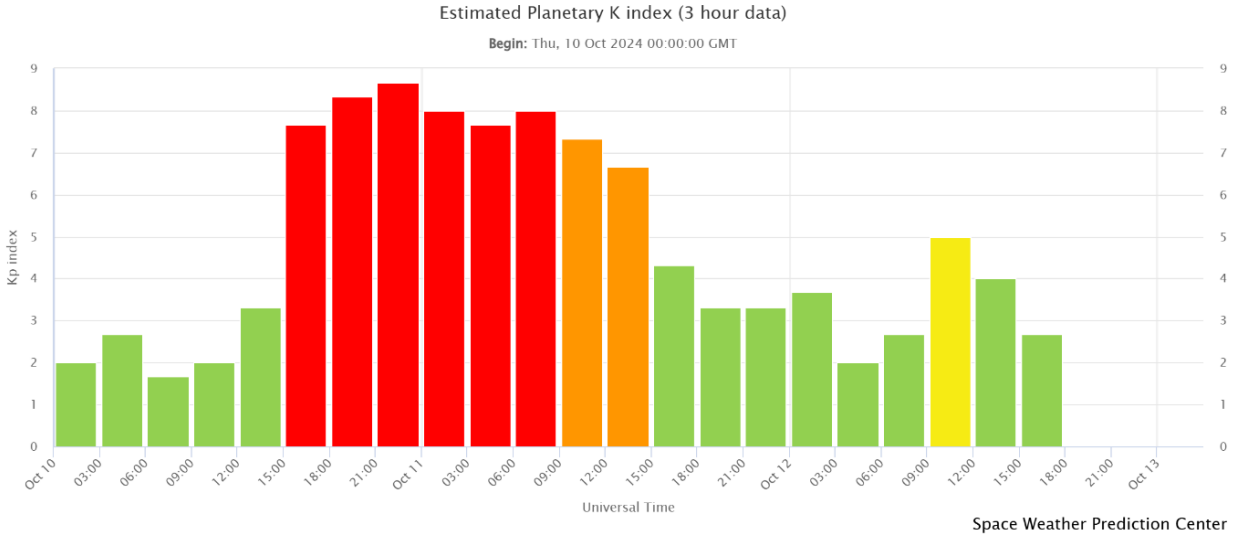


**Figure 5:** The Kp index values during the geomagnetic storm of October 10-11. (http://www.swpc.noaa.gov/products/planetary-k-index)

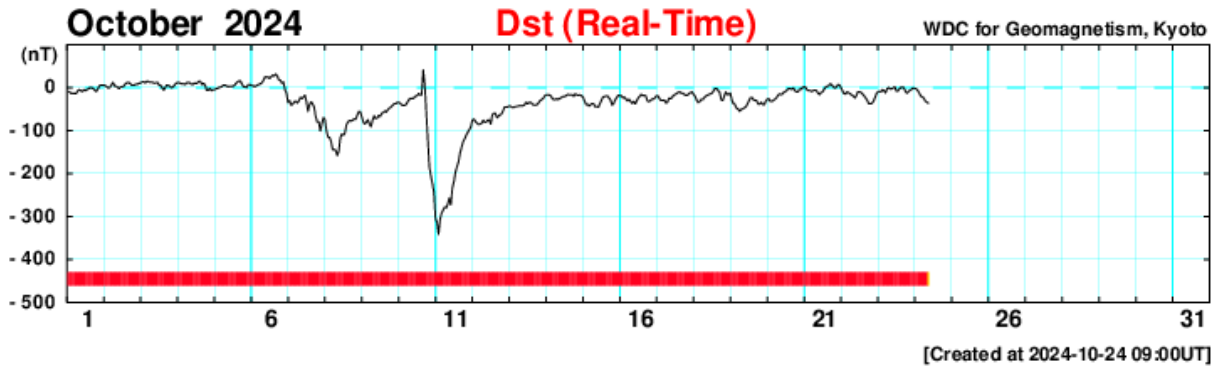


**Figure 6:** The variation of Dst index during the geomagnetic storm of October 10-11.

(Real-time (Quicklook) Dst Index Monthly Plot and Table (kyoto-u.ac.jp))

## 5. Cosmic rays

The results of the geomagnetic storm were spotted on the cosmic ray intensity. A Forbush decrease started on October 11, 2024 as a result of the arrival of CME. The cosmic ray intensity as recorded at the Athens neutron monitor station (cut-off rigidity 8.53 GV) is illustrated in Figure 7.

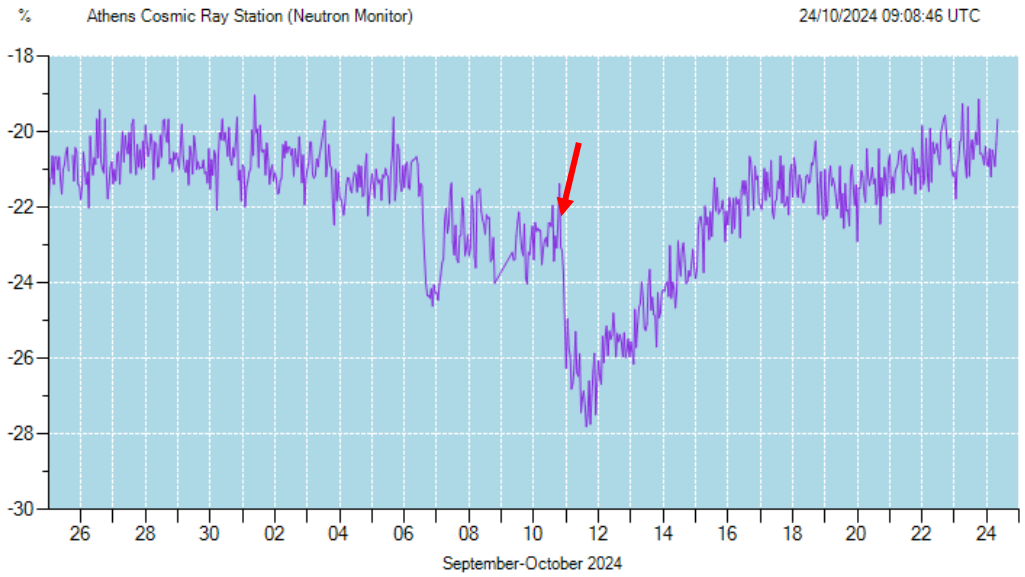


**Figure 7:** The counting rate of the Athens Neutron Monitor Station during the studied period (Home (uoa.gr))

## 6. The ap Prediction tool

The ap Prediction tool (Mavromichalaki et al. 2024a; 2024b) estimated the arrival time of the CME to the Earth of the above geomagnetic storm based on the EAM model predictions (Paouris and Mavromichalaki 2017a; 2017b) (Figure 9).

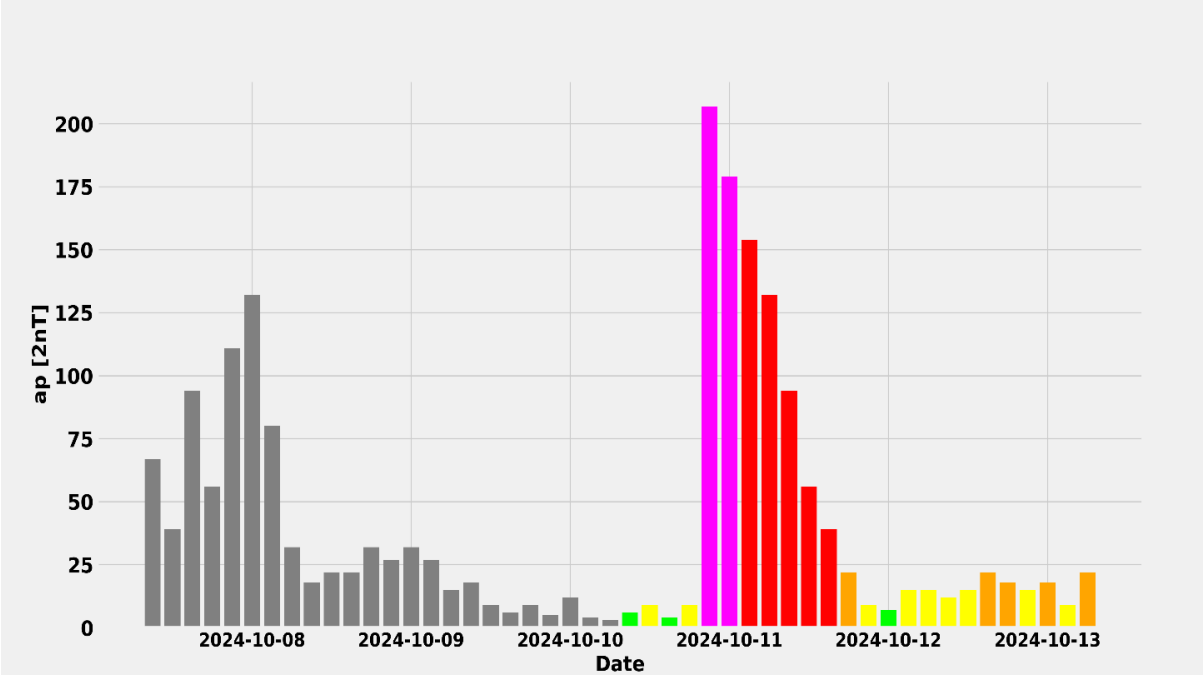


**Figure 9:** Coloured scaled plot of ap values showing in grey color past 72 hours from October 07, 2024 to October 10, 2024 (actual data provided by GFZ) and the forecasted values for the next 72 hours from October 10, 2024 to October 13, 2024. (http://appredict.phys.uoa.gr/)

The expected ap max value was calculated equal to 207nT ($k_p=8^0$) on October 10, 2024 at 21:00 UT by the tool. However, the actual ap index reached its max value of 300nT ($k_p=9^-$) on October 10, 2024 at 21:00 UT, as reported by GFZ (http://www-app3.gfz-potsdam.de/kp_index/qlyymm.html). Moreover, the storm started on October 10, 2024 at 15:00 UT with the actual Kp index equal to $k_p=8^-$.

**Concluding we can say that the automated ap tool predicted successfully the geomagnetic storm of October 10-11, 2024. The ap tool also predicted with high accuracy the arrival time of the CME and the level of the geomagnetic storm.**

References:


- H. Mavromichalaki, M.-C. Papailiou, M. Livada, M. Gerontidou, P. Paschalis, A. Stassinakis, M. Abunina, N. Shlyk, A. Abunin, A. Belov, V. Yanke, N. Crosby, M. Dierckxsens and L. Drube : 'Unusual Forbush Decreases and Geomagnetic Storms on 24 March, 2024 and 11 May, 2024', Atmosphere 2024, 15, 1033, https://doi.org/10.3390/atmos15091033
- H. Mavromichalaki, M. Livada, A. Stassinakis, M. Gerontidou, M.-C. Papailiou, L. Drube and A. Karmi: 'The ap Prediction Tool Implemented by the A.Ne.Mo.S./ NKUA Group', Atmosphere 2024, 15, 1073, https://doi.org/10.3390/atmos15091073.
- E. Paouris and H. Mavromichalaki: 'Effective Acceleration Model for the arrival time of interplanetary shocks driven by coronal mass ejections', Solar Physics, 292, 180, 2017 a, 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, 2017 b, doi: 10.1007/s11207-017-1050-2.