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Storms on Ionosphere during Nov 2021

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ABSTRACT: The paper mention results of the studies referred to the geomagnetic storms during Novenber 2021 on ionosphere during solar cycle 25th. The solar activity governs the interaction of magnetosphere with solar wind and Earth's magnetic field, this influence of magnetosphere is called Geomagnetic storm. The need to study Geomagnetic storm is to overvie the current moving through the ionosphere. We have used ionospheric data at Low, mid and high latitude station. The absorption and ionization of the ionospheric medium depends on solar activity. This is due to geomagnetic storms that occurred around the same time. The impact of the geomagnetic storms is seen at Low, mid as well as high latitude ionosphere. Comparison among all the latitudes shows that the values of foF2 at high latitude are quite less as compared to low and mid latitude. We have found that the effect of solar and geomagnetic storm disturbances is strongest at the low latitude and weakest at the high latitude during the geomagnetic storm time.

Keywords: *Geomagnetic Storm, Solar activity, frequency, Ionosphere, Ionization.*

1. Introduction

The sun is a powerful star and the primary source of energy on the planet earth. The dynamics of the sun's magnetic field is primarily governed by internal dynamo processes which can be quite sporadic in nature. During Nov-2021, Earth experienced a veritable SAR storm. SARs may look like auroras, but they are not the same. Auroras appear when charged particles rain down from space, hitting the atmosphere and causing it to glow like the picture tube of an old color TV. SARs form differently. They are a sign of heat energy leaking into the upper atmosphere from Earth's surface. SARs were discovered in 1956 at the beginning of the Space Age. In fact, SARs are neither stable nor auroras. SARs are among the reddest things in the sky, with a monochromatic glow at 6300 Å that comes from atomic oxygen in the upper atmosphere. Unfortunately, the human eye is relatively insensitive to light at this wavelength. SARs are usually so faint that no one notices when they pass overhead. "At the peak of a solar cycle we typically see 30 SARs per year near Boston".

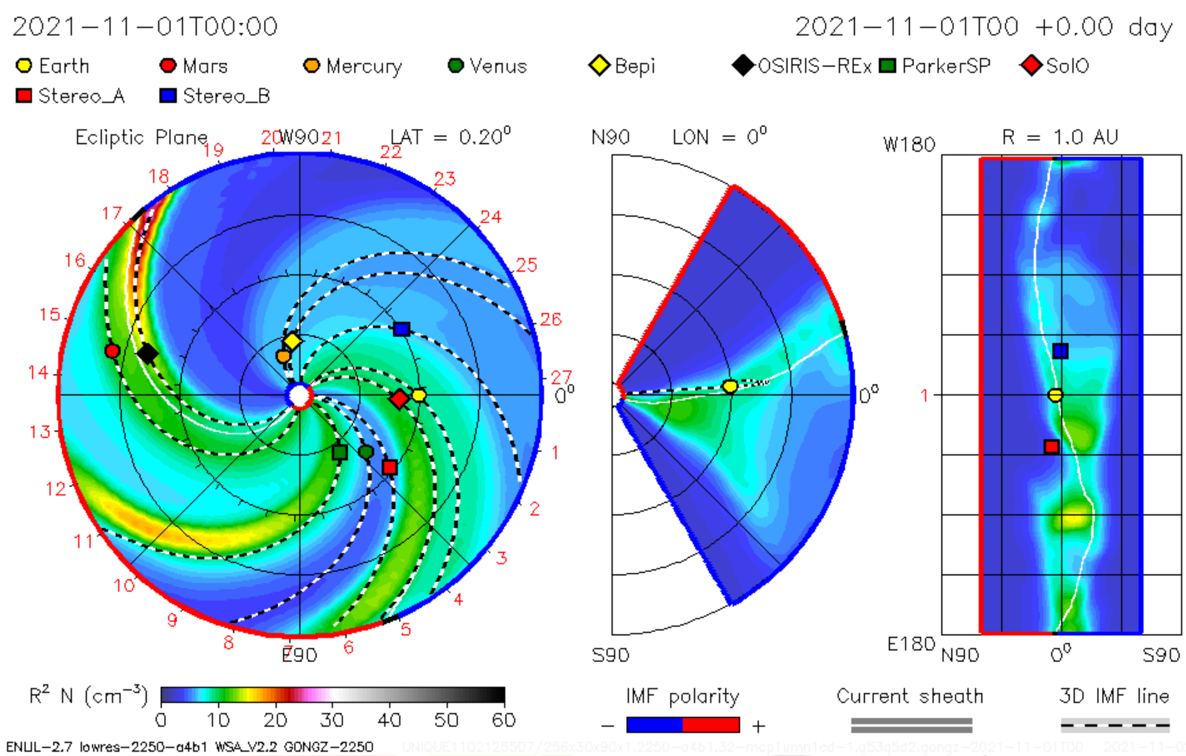
The high interaction between solar wind and magnetosphere is a critical driver for the upper atmosphere variability. The characteristics of these variations change considerably when the solar wind is modified by interplanetary coronal mass ejections (ICME) or co-rotating interaction regions (CIR). Thus, Ionospheric perturbations can be observed on different time scales and of different strength, Forecasting Ionospheric disturbances due to geomagnetic storms driven by ICME or even CIR is a major challenge that is being pursued and already carried out by various institutions. In this study, the idea of an improved global forecast model is presented and the basic concepts are validated. The model is able to provide 24 h forecast of Ionospheric disturbances even during significant solar storms and describes Ionospheric perturbations in high local and spatial resolution based on the observed solar wind conditions and information from historical storm events.

2. Data and Methods: properties of the solar wind are measured by the National Aeronautics and Space Administration (NASA) satellite missions Advanced Composition Explorer (ACE) and Deep Space Climate Observatory (DSCOVR). The data of the instruments on board these satellites are provided in real-time and are used by different institutions to monitor and forecast space weather events. The NOAA National Oceanic and Atmospheric Administration provide the data on board these processes of ionosphere. The geomagnetic data from the wdc Japan helps to provide the dst values of the storms to confirm the strength of storms.

It started with two active regions on the Sun – {places where the Sun's magnetic field is especially intense}. All the active regions present on the Sun on Nov. 1 shown on a magnetic map of the Sun created by the Helioseismic and Magnetic Imager (HMI) instrument aboard NASA's Solar Dynamics Observatory. Pay special attention to Active Region (AR) 12887, toward the bottom right, and AR 12891, near the middle of the Sun.

First Nov, AR 12887 erupted with a C1.3-class flare, reaching peak brightness at about 2 p.m. EDT. (Solar flares are divided into A, B, C, M and X-classes, each class ten times stronger than its predecessor.

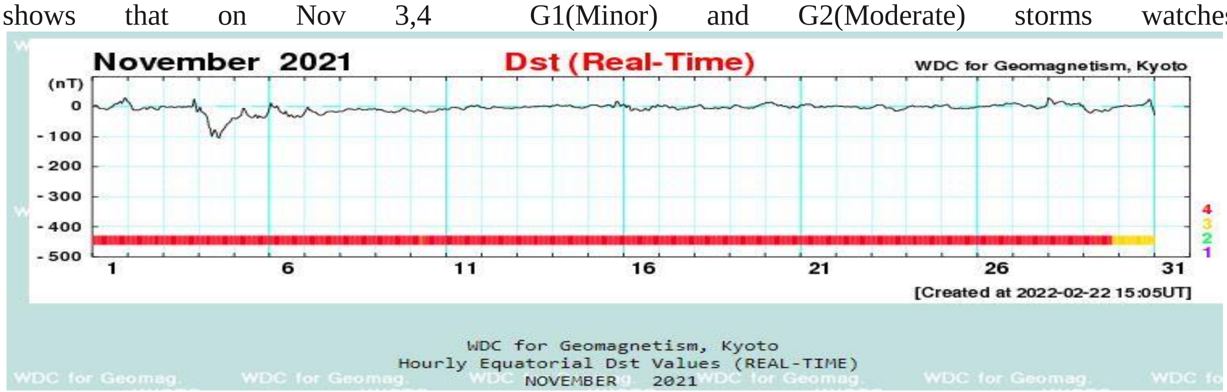
Classes A through C typically have little to no effect on Earth.) Three hours later, an even brighter C4-class flare followed; two hours after that, an M1.6-class flare erupted from AR 12891 towards the center of the Sun. The Solar Dynamics Observatory's Atmospheric Imaging Assembly instrument captured images of each flare at 193 Angstroms, a wavelength that highlights hot solar material more than a million degrees Fahrenheit.



The ENLIL model simulation the three CMEs as they merge and travel toward Earth. Credit: NASA/M2M

The simulations suggested that the three CMEs would blend together, creating a shockwave headed towards Earth and expected to arrive sometime late on Nov. 3 or early on Nov. 4.

The graph below shows the Dst value of srorms during November 2021. The graph shows the strength of storms and it shows that on Nov 3,4 G1(Minor) and G2(Moderate) storms watches to effect.



Several CME's (Coronal Mass Ejection) erupted from the Sun on 01-02 Nov. CME erupted from the southwest area of the Sun to include one associated with a C4 flare from NOAA/SWPC region 2887. This was followed by a full halo CME related to an M1 flare from the region 2891 near center disk. Confidence in a measure of earth directed components to these CMEs is moderate while there is less confidence in timing and intensity.

Earth's magnetic field and thick atmosphere protects its surface (and us) from most effects of solar eruptions. But the highest layers of our atmosphere can undergo many changes. As a CME collides with Earth's magnetic field, it can generate geomagnetic storms: disturbances to Earth's magnetic environment that have a variety of impacts, including the northern and southern lights.

By 5 p.m. EDT on Nov. 3, the shockwave had arrived. Magnetometers across the planet registered a Kp index – a measure of disturbance to Earth's magnetic field – of 7, corresponding to a strong geomagnetic storm. Kp index levels range from 0 (quiet) to 9 (intense).

In the early morning hours of Nov. 4, aurora watchers across the Northern Hemisphere documented the results. The animated gif below shows the aurora over Utah, captured by NASA JPL producer Bill Dunford on Nov. 4 between 1:30-1:42 a.m. MDT.

This geomagnetic storm is now over, but as Solar Cycle 25 picks up and the Sun becomes more active, there is sure to be more.

3. Discussion and Conclusion:

The Bz component of the interplanetary magnetic field dipped quickly down to during to which quickly sparked moderate G2 geomagnetic storm conditions making aurora visible all over Sweden, Scotland and even The Netherlands to just name a couple of places.

The Bz did turn mostly northward around midnight UTC, but later in the night and morning the Bz really dipped southward for a couple of hours going as low as -18nT. This combined with the high solar wind speed caused strong G3 geomagnetic storm conditions) and sparked truly amazing aurora at many locations in Canada and the northern USA.

The Bz has rotated firmly northward now which is really hampering further storm conditions. The show is over... for now... as there might be a new interesting sunspot region just behind the east limb!

The shockwave arived on 3rd Novembe and Magnetometers across the planet registered a Kp index – a measure of disturbance to Earth's magnetic field – of 7, corresponding to a strong geomagnetic storm. Kp index levels range from 0 (quiet) to 9 (intense).

The combined CME has arrived, slightly earlier than forecast. The CME from November 2 overtook the CME from November 1, and the combined event was first detected as a shock wave at 19:57 (3:57 PM EDT) by the spacecraft using its solar wind monitor (DSCOVR is located 1 million miles – 1.6 million km – from Earth in the direction of the sun.) Then a strong compression of Earth's magnetosphere due to this shock was detected at 21:29 UTC (5:29 PM EDT). This set off a G1 geomagnetic storm at 21:38 UTC (5:38 PM EDT) increasing to a G2 geomagnetic storm at 22:05 UTC (6:05 PM EDT). NOAA has issued a warning for a geomagnetic storm of G3 or greater!

Earth's magnetic field is calming down as the planet comes out of the 20-hour-long strong geomagnetic storms followed by coronal mass ejection from the Sun. The eruptions from the Sun struck the planet's magnetic field triggering a G3 category geomagnetic storm spiking auroras on lower latitudes.

The eruptions from the sun hit Earth's magnetosphere at an exponential speed of 583 kilometres per second. The magnetosphere is formed by the interaction of the solar wind with Earth's magnetic field.

According to spaceweather.com, the glow of a strong (G3) geomagnetic storm spread almost to Los Angeles. The agency reported that the CME that sparked the display was a special "Cannibal CME" that is a mashup of multiple solar storm clouds striking Earth all at once.

According to the Space Weather Prediction Center under the US' National Oceanic and Atmospheric Administration, a coronal mass ejection is large expulsion of plasma and magnetic field from the Sun's corona. They can eject billions of

tons of coronal material. CMEs travel outward from the Sun at speeds ranging from slower than 250 kilometres per second to as fast as near 3000 km/s. The fastest Earth-directed CMEs can reach our planet in as little as 15-18 hours.
The cannibal CMEs that Sun erupted this time contained tangled magnetic fields and compressed plasmas that sparked auroras. A steep jump in transverse magnetic fields, density and speeds of the plasma wind signatures were noticed as the erupting struck Earth's magnetic field. The Sun has been highly active for a week now as it hurtles dangerous storms towards the inner planets of the solar system.
According to NASA, a very efficient exchange of energy from the solar wind into the space environment surrounding Earth losted. The largest storms that result from these conditions are associated with solar coronal mass ejections (CMEs) where a billion tons or so of plasma from the sun, with its embedded magnetic field, arrives at Earth.

A full-halo coronal mass ejection (CME) left the Sun early on 2nd Nov, associated with an M-class solar flare. This CME is directed towards the Earth and we expect it to arrive late on the 3rd or early on 4th Nov.

There have also been several more CMEs in the past few days, which might have some earthward component. There is a chance that some or all of these CMEs will interact with each other, increasing the chance for enhanced geomagnetic activity. This could lead to some periods of STORM conditions following the arrival, and throughout the 4th Nov.

Assuming clear, dark skies, there is a chance of seeing the aurora tonight (3rd) and early tomorrow (4th). Those in Scotland, northern England and Northern Ireland have the better chance if the weather is favourable.

The correlation in between sunspot number and solar flare occurred has was being aimed for different flare classes. The resultfollows as below:

(i) The solar flare effect (sfe) was stronger in SC23 than SC24 while equinoctial months had the highest magnetic crochet. The respective highest ΔHsfe values of 48.82 nT and 24.68 nT were obtained in the month of September while the lowest values of 8.69 nT were recorded in June for cycle 23 and 10.69 nT in July for cycle 24.

(ii) C and M-class flares strongly correlated with sunspot number with the respective correlation coefficients of 0.93/0.97, 0.96/0.96 during SC23/24. However, the correlation coefficient for X-class flare was 0.60/0.56.

(iii) The negative correlation between A and B-class flare and sunspot numbers (−0.43/−0.54 and −0.42/−0.39) during SC23/24 was related to the frequent occurrence of such classes of flare during solar minimum.

(iv) There was a delay of few minutes in the response of the three geomagnetic components to the SFs. Generally, the magnetic crochet of the H component was negative at mid latitudes in both hemispheres and positive at low-latitudes.

(v) The peak amplitude of the Sfe was stronger for the stations around the magnetic equator and very low when the geomagnetic field components were close to their nighttime values.

The geomagnetic indices are obtained from the World Data Center for Geomagnetism, Kyoto, Japan (http://wdc.kugi.kyoto-u.ac.jp/, WDC, 2021). The list of substorms is collected from the SuperMAG website (https://supermag.jhuapl. edu/, SuperMAG, 2021). The F10.7 solar fluxes are obtained from the Laboratory for Atmospheric and Space Physics (LASP) Interactive Solar Irradiance Data Center (https://lasp.colorado.edu/lisird/, LISIRD, 2021).

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