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CORRELATION SOLAR FLARES WITH THREE ACTIVE REGIONS AND ATTENUATION OF HIGH-FREQUENCY SIGNAL WITHIN THREE DAYS

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Abstract

The word Sun or al-Shams (in Arabic) is mentioned 33 times in 32 verses of the Qur'an. To date, theoretical study of the Sun has been generally successful in providing an understanding of the surface properties of the Sun. Ionosphere disturbance and solar flares are closely related events where the HF communication that depends on the ionosphere region may disrupt and cause a major shut down in the worst case. In this study, the recent condition of the solar flare event produced by associated active regions correlation with the ionosphere disturbance on the Earth has been analyzed. At the end of 2020, there are many active regions (AR) that can be observed as the Sun was in an active state. This study limits the active regions and solar flares for three days (23rd November 2020 – 25th November 2020). 15 solar flares have been detected with 4 active regions (AR) within these three days. Active regions captured by the sun magnetogram are AR2783, AR2784, AR2785, and AR2786. AR2786 is the active region with a huge size of sunspots. Although AR2784 was observed, however, there is no sign of flares ejected within these three days. The number of sunspots varied from 33 to 40. The observation on the sun through HMI magnetogram and SDO Fe IX/X 171 Å where the image can be accessed from the solar monitor website. The observation correlates with ionosphere disturbance by observing the attenuation of HF communication through D-region absorption prediction (D-RAP). The ionosphere will undergo excess photoionization due to radiation ejected during a solar flare.

Keywords: *Flares, Burst, Active, Region, Attenuation.*

INTRODUCTION

Sun is the closest star to the earth. Almost all solar activities affect humans, for instance, solar flares, coronal mass ejections (CMEs), sunspots, and prominence. The word Sun or al-Shams (in Arabic) is mentioned 33 times in 32 verses of the Qur'an. Sun monitoring generally is an activity that measures and estimates the effect of solar activities on the space weather and our Earth. It must be done continuously as its condition keeps changing over time to explain and forecasting an event that may affect our universe. Made up of a loose connection of diverse dynamical processes around the solar atmosphere includes visible flare, radio-noise emission, enhanced x-ray emission prominence activity, etc. It interacts with the Earth through its particle emission from different windows of electromagnetic radiation.

The solar activity gives out many phenomena that affect the Earth in some way and solar flare is one of them. Through the solar flare, a burst of radiation is emitted in various wavelengths from radio wave to gamma-ray wave of the electromagnetic spectrum and it occurs mostly during solar maximum rather than the solar minimum (Hegde et al., 2018a; Sharma & More, 2017; N. Zakaria et al., 2019). A solar flare is said to be an impactful event to the satellites and radio transmission and there were in history that electrical power in Quebec was destroyed by a flare in 1989 (Ross, 2020; Simmons, 2017). Solar flare also mostly relates to radio blackout tragedy like what happened in May 1967 observed by the US military and October-November 2003 in Sweden that affected 50,000 people(Eastwood et al., 2017). Thus, it is important to study solar flares because various radiation may penetrate through the interplanetary space and our atmosphere. This may cause danger to astronauts, electronic space instruments, and Earth's communication.

i. Solar Flares

One of the methods to measure solar flares is by using the XRS instruments. By classifying the solar flare based on the events' peak flux (Wm-2) of 1-8Å measured by the XRS instrument onboard GOES-15 will produce a graph of the power signal as shown in Figure 1. This figure gives reviews and information on the power signal of the flare for three days. In normal conditions, flare ejected by the sun gives an insignificant effect to the ionosphere region of the Earth. However, solar flare events closely relate with ionospheric disturbance where x-rays radiations, with below 1 nm wavelength and high frequencies, gives excess ionized O2 and N2 by penetrating through the Earth atmosphere to the lower region of the ionosphere, and the rapidly increased ion density in the region called as Sudden Ionospheric Disturbance (SIDs) (Dyrda et al., 2015; N. A. Zakaria et al., 2019).

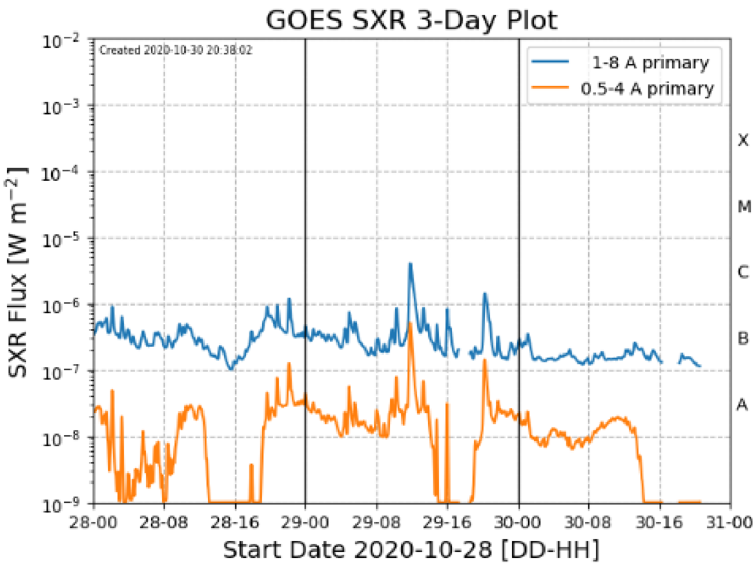


Figure 1: GOES SXR 3-day plot with flux power signal in Wm-2 (left side) and class flare (right side) (source: solar monitor)

ii. Sudden Ionospheric Disturbance (SID)

Ionosphere response to flares has been an interesting topic for astrophysicists until today. Doppler sounding system and Global Positioning System (GPS) have been implemented since the 1990s to monitor the ionospheric region effect due to solar flare events. Both systems went sudden fade out due to the abnormal condition within the ionosphere layer and GPS dual frequency with 24 satellites distributed around the atmosphere of the globe is said to be and the ideal system with real-time and higher precision, higher spatial and temporal resolution data (Liu, 2004; Zhang, 2005). Sudden increase of electron density in the layers of the ionosphere (D, E, F region) of the Earth is the subject of the solar flare phenomenon where the intensity of narrow ribbon of current flowing eastward and electron density in the F-region increase and forming a unique set of ionization in E layer (Liu, 2004; Liu et al., 2006).

D-region is the lower region of the ionosphere. This layer will disappear after sunset and will be enhanced by the additional photoionization process during a solar flare. The ion density in the region will attenuate the radio waves. attenuation is related to the frequency; where higher frequency will cause higher attenuation (Hegde et al., 2018b). Attenuation is the absorption of wave signal that will reduce the strength and give a weak signal to the receiver. High frequency (HF) radio is used as communication of ionospheric radio waves propagation that has long coverage, high mobility, persistence, and low cost that may be affected by many kinds of disturbance due to the changes in ionospheric layers (Uryadov et al., 2018).

Thus, demonstration on solar flare can disrupt radio signals over large geographical extend to a few hours that give a big impact on communication and navigation radio application observed when the total fadeout and turned into a partial fadeout where the highest frequency echoes show up first on ionograms after solar flare event in September 2017 (Fagundes et al., 2020). In this work, we observe the correlation of the solar flare and the ionospheric disturbance by comparing the signal attenuation during the flares event

METHODOLOGY

All data for the study was retrieved from National Oceanic and Atmospheric Administration (NOAA) website, space weather monitor, and space weather live websites. NOAA websites provide solar flare data with its active region location and classified flares. Observation of the solar sunspot based on the magnetogram and the SDO/AIA Fe IX/X at 171 Å band Space weather monitor provides the observation data for SID events of HF signal analyzation with flares associated while Space Weather Live used to identify the Sun's condition that may relate with the ionospheric disturbance (includes solar wind speed, solar wind density, Kp index, etc.)

All data has been analyzed to see the relationship between solar flare events and ionospheric disturbance. These websites and data archived are mainly used by astrophysicists to make the research and has been analyzed which makes it reliable data for studies. The data has been retrieved and recorded using Microsoft Excel.

RESULTS AND DISCUSSION

This event started from 23rd November 2020- 25th November 2020 in the 25th solar cycle. There are 15 solar flare events detected over three days in November 2020. The Sun is getting active and AR2786 is one of the huge sunspots. Interestingly, there are 3 active regions formed within 3 days. It is known that the magnetic field behaviors are due to the coherent flux tube between those active regions and play important roles in solar eruptions. There must be a convective energy transform between them. Most strong flares and Coronal Mass Ejections (CMEs) originated from the high concentration of ARs magnetic field clusters (Jiang et al., 2019) The number of sunspots varied from 33 to 40. 15 solar flares occurred simultaneously. It started with active region AR2783 before the formation of AR2785 and AR2786 triggering solar flare class B and C.

From the observation, we can see class B and C observed repeatedly with a minimum of 8 x 10-7 W/m-2 and a maximum of 43.0 x 10-7 W/m-2. The Kp index used to characterize the magnitude of geomagnetic storm shown the scale of 0-3 for these three days which indicates a quiet condition at the time of solar flare event day. Therefore, the disturbance that occurs in the ionosphere region is mainly caused by solar flare events. Figure 2 shows the X-ray flux plot for three days recorded by the XRS instrument. The blue line is the effective wavelength (1.0 Å – 8.0 Å) to compare the intensity of the flares.

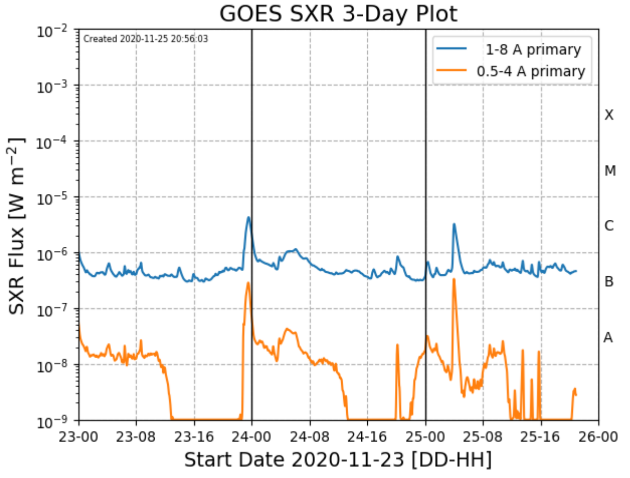


Figure 2: X-ray flux for three days (source: solar monitor)

Figure 3 represents the magnetogram of the Sun with the location of each active region on 25th November 2020. AR 2786 has the biggest size among these four active regions however 2785 recorded higher intensity of flare on 23rd November 2020.

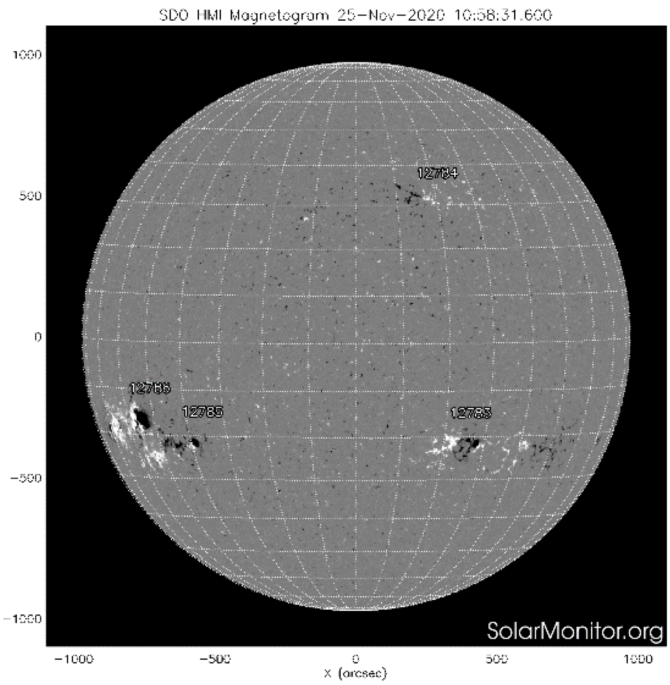
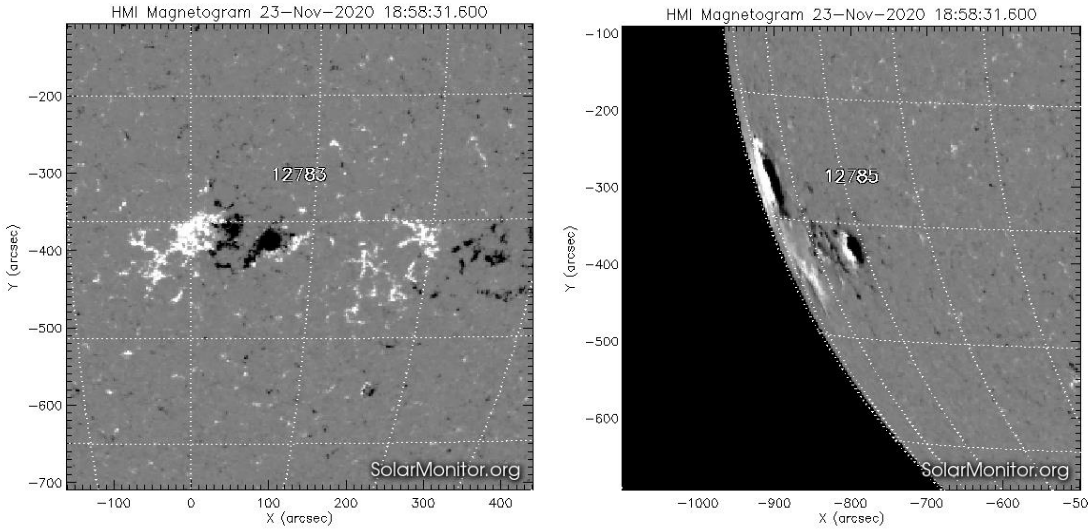


Figure 3: Magnetogram of the Sun (Source: SDO/AIA)

AR2783 classified as α(unipolar) magnetic type for the last three days before it produced two B8 flares at daytime on 23rd November 2020 and develop into β(bipolar) while higher class flare detected on the same day with C1.3 and C4.3 produced at AR2785 at night-time.

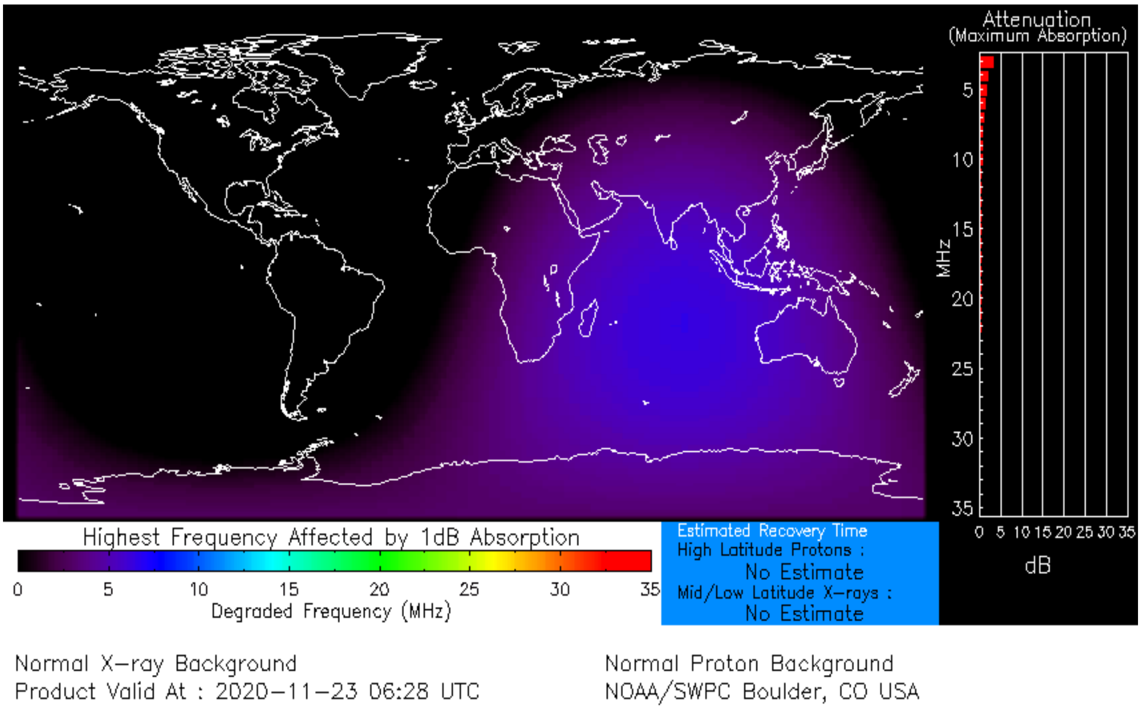
The solar minimum event, B8 class flare on 23rd November 2020, and the maximum event, C4.3 on the same day chosen to compare the effect on the ionosphere region of the Earth. B8 flare was produced by while C4.3 was produced by AR2785. As shown in Figure 4, AR 2785(ii) which has its peak C4.3 at 2335 UTC has a larger (120MH) size than AR2783 (90MH). However, AR 2783(i) has a greater number of sunspots than AR2785.



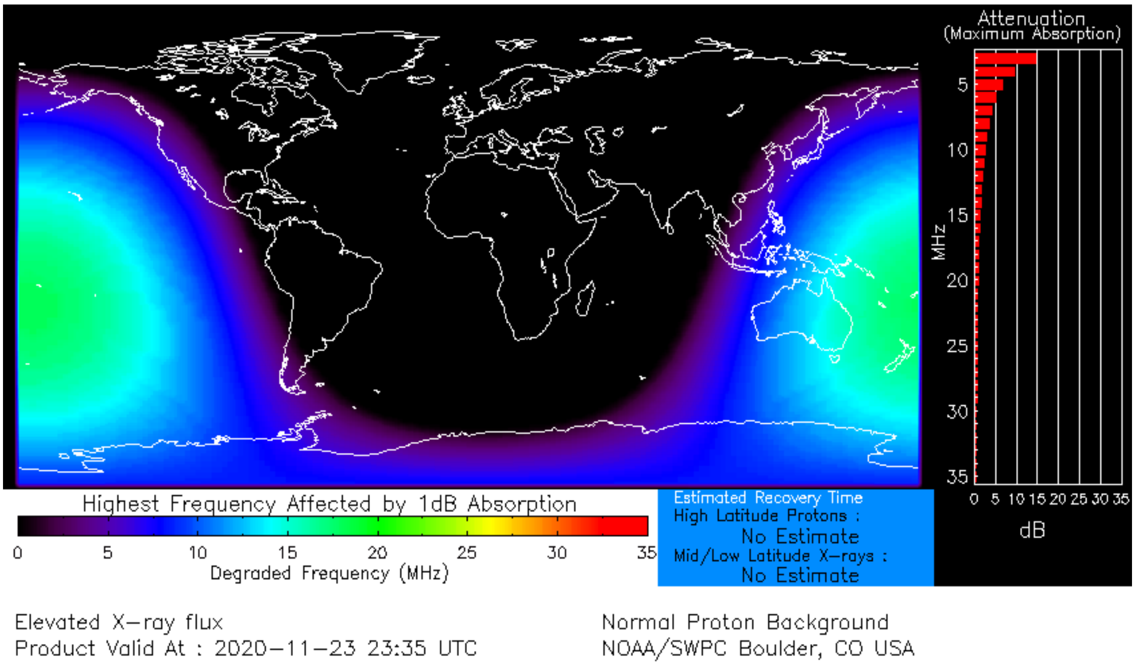
i)AR2783 ii) AR2785

Figure 4: The active region (Source: HMI Magnetogram)

Both regions on 23rd November 2020 are β-magnetic classification where the sunspots with a simple division of polarities of positive and negative. The darker parts are the S-polarity region, and the white parts are the N-polarity region. Throughout the day of the event, the D-region absorption Prediction (D-Rap) recorded by NOAA Space Weather Prediction Centre was used to correlate the solar flare event and the ionospheric disturbance. We can see in Figure 5, D-Rap recorded that the frequency affected in 1db absorption reached as high as 20MHz and X-ray radiation elevating detected at the peak time of a) C4.3 flare and b) 5-6MHz with normal X-ray background for B8 solar flare event. This shows the SEP events and HF radio communication impacted more during the C4.3 solar flare event where it depends on the reflection of the signal on the ionosphere D-layer.



a) Peak time of B8 flare



b) Peak time of C4.3 flare

Figure 5: D-Rap of the ionosphere region on the peak time of flare

Attenuation during the C4.3 flare event is higher than the B8 event, therefore it affects the HF communication as the wave will eventually fade out as it passed through the D-region with increased electron density.

CONCLUSION

The magnetic field of the active regions reconnecting and produced the solar flare and we studied how it affects the HF communication caused by SID. Comparing the size of the sunspot, AR2785 which has a bigger size active region will produce greater solar flare. The ionosphere will undergo excess photoionization due to radiation ejected during a solar flare. Therefore, the electron density of the region increased where the phenomenon called Sudden Ionospheric Disturbance (SID). Therefore, the attenuation of the signal reflecting will high and low signals will be received, and this study reconfirms that solar flares event does affect the radio telecommunication along with satellite systems.

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