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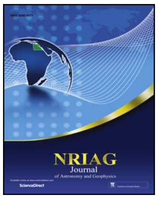

Full length article

Solar flare induced cosmic noise absorption

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ABSTRACT

Solar flare events are a major observing emphasis for space weather because they affect the ionosphere and can eject high-energy particles that can adversely affect Earth's technologies. In this study we model 38.2 MHz cosmic noise absorption (CNA) by utilising measurements from the Imaging Riometer for Ionospheric Studies (IRIS) at Kilpisjärvi, Finland obtained during solar cycle 23 (1996–2009). We utilised X-ray archive for the same period from the Geostationary Operational Environmental Satellite (GOES) to study solar flare induced cosmic noise absorption. We identified the threshold of flare (M4 class) that could bear significant influence on CNA. Through epoch analysis, we show the magnitude of absorption that each class of flare could produce. Using the parameters of flare and absorption we present a model that could provide the basis for nowcast of CNA induced by M and X-class solar flares.

1. Introduction

Radio waves passing through an ionised medium cause the electrons to vibrate. If these electrons collide with heavy particles, energy is transferred from the wave to the medium in the form of plasma thermal energy and the rate of wave attenuation is then dependent on the number of collisions per oscillation. The electron density, the gyro frequency, and the electron collisions with neutral atoms and molecules affect the passage of radio waves through the ionosphere [e.g. Schunk and Nagy, 2009; Hargreaves, 1995; Tanaka et al., 2007]. Cosmic radio noise refers to the background radio frequency radiation from galactic sources, having constant intensity during geomagnetically quiet periods. The cosmic noise intensity measured with ground-based receivers will fluctuate corresponding to the level of ionosation in the earth’s ionosphere. Increased ionisation results in absorption of the cosmic radio noise as it passes through the ionosphere. Comparing the noise level recorded by ground-based equipment such as riometers with the expected value in the absence of the ionospheric absorption, the level of absorption can be computed from:

Where A is absorption in decibel, p is the measured noise level and is the noise level measured in the absence of absorption [Browne et al., 1995].

Solar flares are sudden explosive releases of stored magnetic energy in the atmosphere of the Sun causing sudden brightening of the photosphere which can last from few minutes to several hours [Keith, 1991]. During solar flare events, particles and electromagnetic emissions can affect the Earth’s atmosphere. The three phases of flare events are the pre-flare phase, the rise phase and the main phase. The pre-flare phase is characterised by slowly rising prominence on the solar surface due to some weak eruptive instability. Normally, this phase lasts for half an hour and is accompanied by X-ray brightening. During the rise phase, the stretched magnetic field lines start to break and reconnect; in the process, prominences erupt more quickly with a steep rise in Hα and soft X-ray emissions. During the main phase, the reconnection point rises, hot X-ray loops and Hα ribbons are created [e.g. Hudson, 2011]. The explosive release that accompanies flare event leads to the emission of ultraviolet (UV) and X-ray radiation and can drive energetic particle precipitation. At the time of the flare, the ionisation of the D region of the dayside ionosphere can increase [e.g. Stauning, 1996], resulting in the so-called ‘Sudden Ionospheric Disturbances’ (SIDs), and the associated absorption is known as sudden cosmic noise absorption (SCNA). Nwankwo et al. (2016) identified merits in studying sudden ionospheric disturbances related to prompt X-ray flux output from solar flares.

The duration of SCNA absorption is usually of the order of the flare [Stauning, 1996; Longden et al., 2007]. Fig. 1 below shows the incident power and absorption plots from the central beam of IRIS riometer at

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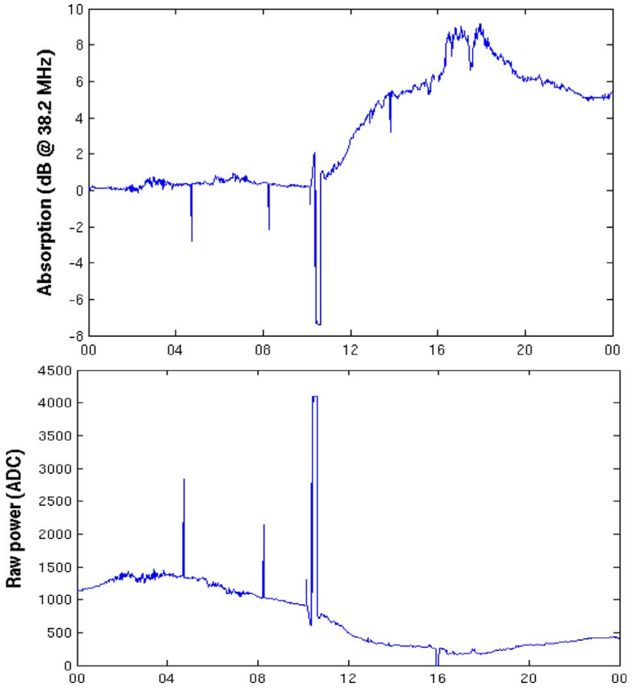

Fig. 1. Figure 6.1: Cosmic noise absorption event following solar flare of 14th July, 2000. Panel (a) shows the derived cosmic noise absorption from incident power on the y-axis and local time variation on the x-axis. Panel (b) shows incident cosmic noise power detected by central beam (beam 25) of IRIS at Kilpisjärvi, Finland, 69.05 deg N, 20.79 deg E) the x-axis shows local time variation. The arrow on panel (b) shows the time of commencement of the X-class flare just after 10:24UT, gradual increase in riometer absorption began just after 10:24UT from about 0.2 dB up to 8 dB at 17:00 h.

Table 1
Classification of GOES soft X-ray flare.

Classification	Peak Flux in1-8 Å Range (Wm^{-2})
A	$x < 10^{-7}$
B	$10^{-7} \le x < 10^{-6}$
C	$10^{-6} \le x < 10^{-5}$
M	$10^{-5} \le x < 10^{-4}$
X	$10^{-4} \le x$

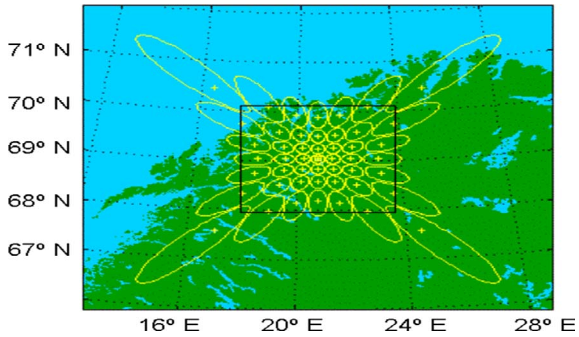

Fig. 2. Beam projection of IRIS at 90 km altitude. The contours define the –3 dB points and the black square shows the calculated field of view used in the IRIS images.

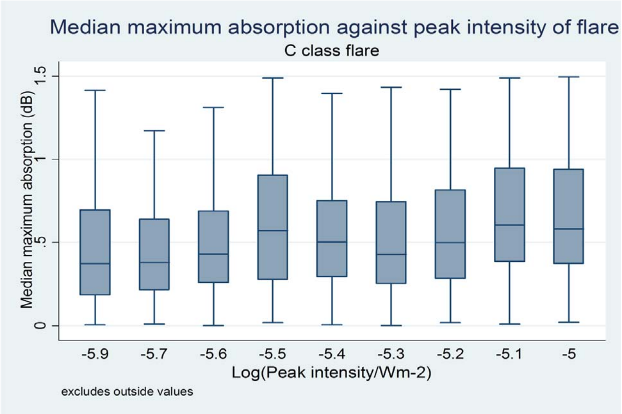

Fig. 3A. Plot of median maximum absorption against log of flare intensity for C-class flares. Class (i.e. C1–C9) bins the flares and the median peak absorption computed for each bin. Here there is no visible trend in median absorption within bin classes.

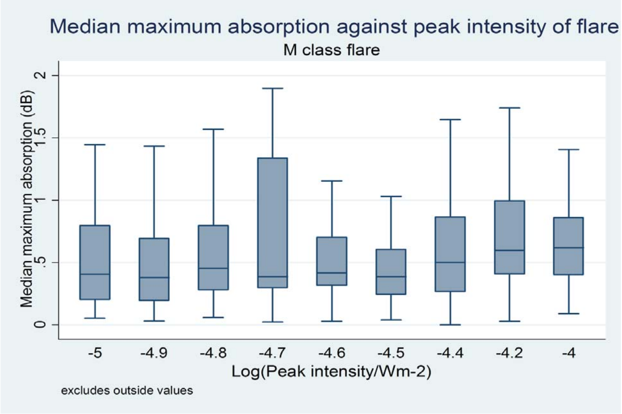

Fig. 3B. Plot of median maximum absorption against log of flare intensity for M-class flares. M-class flares are binned from M1-M9 and the median peak absorption computed for each bin. No trend is observable until class M4, a gradual increase in median absorption signature within the bin from M4 to upper bin values.

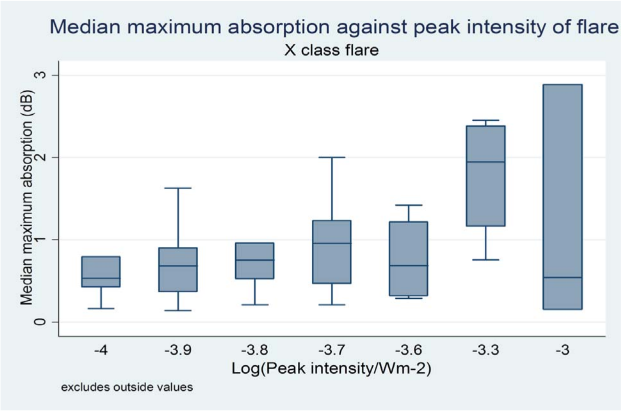

Fig. 3C. Plot of median maximum absorption against log of flare intensity for X-class flares. X-class flares are binned from X1-X9 and the median peak absorption computed for each bin. There are no data in the bins X2 and X3.

Kilpisjärvi during the solar flare of 7th July, 2000. SCNA is observed following apparent increase in the received noise power. The increase of received power is attributable to an increase in the solar radio emission at the time of the flare. During intense SIDs there can be considerable disruption and even blackouts to radio communications, particularly at the higher latitudes as a result of absorption in the D and lower E regions. Previous studies [e.g. Hultqvist, 1999 and Contreira et al., 2005] associated the flare process to magnetic reconnection within the solar corona in which processed magnetic energy is