Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 58 (2016) 1208–1218

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

www.elsevier.com/locate/asr

Storm-time variation of the horizontal and vertical components of the geomagnetic fields and rate of induction at different latitudes

E.O. Falayi [a,*], O.A. Oyebanjo [a], T.V. Omotosho [b], A.A. Okusanya [a]

[a] Department of Physics, Tai Solarin University of Education, Ijagun, P.M.B. 2118, Ijebu Ode, Ogun State, Nigeria
[b] Department of Physics, College of Sciences and Technology, Covenant University, P.M.B. 1023, Ota, Ogun State, Nigeria

Received 22 February 2016; received in revised form 12 June 2016; accepted 13 June 2016
Available online 18 June 2016

Abstract

The paper presents the hourly mean variation of horizontal (H) and vertical (Z) components of the geomagnetic field and the rate of induction $\Delta H/\Delta Z$ at different latitudes during magnetic storm of 20 March 2001 and 1 October 2001. The results of the analysis revealed that at high latitude stations greater than 60°, the reduction in ΔH component was noticed after the noon time while other stations less than 60° experienced reduction of H in the morning time during the geomagnetic storm. Large amplitude of ΔH and ΔZ were exhibited during the daytime over the equatorial zone, the amplitude decreases from mid latitudes to the dip equator during the nighttime. The daytime enhancement of ΔH at AAE, BAN and MBO suggest the presence of a strong eastward directed current which comes under the influence of electrojet. There were strong positive and negative correlations between ring current (DR) and horizontal component of the magnetic field ΔH. The effect of rate of induction is more significant at high latitudes than lower latitudes, during the geomagnetic storm. More enhancement in rate of induction occurred at nighttime than daytime. This result may be from other sources other than the ionosphere that is magnetospheric process significantly contributes toward the variation of induction.

Keywords: Geomagnetic field; Geomagnetic storm; Electromagnetic induction; Ring current; Coronal mass ejection

1. Introduction

The magnetic field of the Earth is influenced by the high plasma speed infused from a coronal mass ejection (CME). The charged particles deposited in the magnetosphere are later released into the upper atmosphere. The charged particles deposited in the high latitudes cause intense current and leads to the enhancement of the electric field and electrical conductivity. These current have an influence on the geomagnetic field observed by magnetometer. During the magnetic storm, the increased solar wind dynamic pressure acting on the magnetosphere and compress the dayside of the magnetosphere, forcing the magnetopause current close to the Earth surface resulted increase in the horizontal component of the geomagnetic field (H).

Literatures have revealed the influence of solar flare effect on the geomagnetic field components at different latitudes (McNish, 1937; Nagata, 1952; Ohshio et al., 1967; Srivastava, 1974; Raja Rao and Rao, 1963; Sastri, 1975; Rangarajan and Rastogi, 1981; Rastogi et al., 1983; Rastogi, 1975, 1996; Tsunomura, 1998) and such influence results into sudden storm commencement. The disturbance storm time variations of the vertical component (Z) of the geomagnetic field exhibit a large decrease during sudden storm commencement at Thiruvananthapuram, Etaiyapuram, Kodaikanal and Annamalainagar. It was observed that this decrease is not the same in time with the decrease

* Corresponding author.
E-mail addresses: olukayodefalayi@yahoo.com (E.O. Falayi), oyebanjokemi@yahoo.com (O.A. Oyebanjo), omotosho@covenantuniversity.edu.ng (T.V. Omotosho), okusanya_abayomi@yahoo.com (A.A. Okusanya).

http://dx.doi.org/10.1016/j.asr.2016.06.017
0273-1177/

in the horizontal component (H) component, which is as a result of the sub-surface channel, where current are induced by the ionospheric current which produced a large decrease in Z (Rastogi, 2001). Day to day variability during the midday and midnight was investigated along Indo-Russian chain stations, using H and disturbance storm time (Dst) index. The relationship between ΔH and Dst index was 0.8 while the slope regression of 1.0 and 0.5 where noticed at daytime and nighttime respectively. It was concluded that the nighttime tail current has influence on the variation of ΔH due to the ring current disturbances (James et al., 2008). Hasegawa (1960) examined the position of the foci of the ionospheric current which have an influence on the day to day variability in solar quiet (Sq). Rastogi (2006) studied the influence of ionospheric current, magnetospheric current and induced current on equatorial electrojet stations over Central Africa, East Brazil and India, using geomagnetic field components of ΔH, ΔY and ΔZ.

The rate of induction refers to the ratios $\Delta Z/\Delta H$ where ΔZ refers to the total amplitude between the extreme in Z field and ΔH is the excess effect in relation to the planetary effect at the magnetic equator. Numerous investigations have been carried out on the responses of induction effect using H and Z components (Price, 1967; Schmucker, 1970; Rabiu and Nagarajan, 2008). The induction at Etaiyapuram is enhanced during strong electrojet current (Rastogi and James, 2001). Also a daily variation of geomagnetic field Z does not show any abnormal effect as a result of induction, but during the storm time the $Dst(Z)$ shows induction effects (Rastogi and James, 2001). Rastogi (2004) studied the response of the induction effect in central and eastern part of South America, induction seems to be absent, but significant induction effect is observed at Peredinia, Sri Lanka, abnormal conductivity distribution. Falayi et al. (2015) used H and Z to examine the response of ionospheric disturbance dynamo and electromagnetic induction during geomagnetic storms. High ratio of $\Delta Z/\Delta H$ is observed at nighttime because of the reduction on the E region conductivity, which allowed F region electric fields to dominate. The aim of this paper is to examine the variation pattern of ΔH, ΔZ and rate of induction during the geomagnetic storm of 20 March 2001 and 1 October 2001, also investigate the correlation coefficient between ring current (DR) and ΔH.

2. Data and method of data analysis

The set of data used in the present work are obtained from International Real-Time Magnetic Observatory Network (INTERMAGNET, 2015), for the study of variation of the magnetic field. It provides one minute values of the northward (X), eastward (Y), vertical (Z) components of the Earth's magnetic field, while horizontal component (H) is computed using Eq. (1)

$$H = \sqrt{(X)^2 + (Y)^2} \quad (1)$$

The variation in H (ΔH) and Z (ΔZ) were obtained by correcting the hourly departure and the midnight baseline values for non-cyclic variation to obtain the hourly ratios of $\Delta Z/\Delta H$ (Rabiu et al., 2007; Bolaji et al., 2013). The geographic and geomagnetic coordinates of these sites are given in Table 1.

The present work focused on the data acquired during the CME of 20 March 2001 and 1 October 2001 were engaged in the study, the CME observed by LASCO-C2 having the following features, the angular width of the CME (full or partial halo); the speed and the height at which this speed can be measured, obtained from: http://cdaw.gsfc.nasa.gov/CME_list.

To identify the corresponding strength of the geomagnetic storm, 1 hourly values of solar wind speed (Vx) gives the amplitude of the solar wind disturbance, the interplanetary magnetic field (Bz) determines the amount of energy that can be transferred to the Earth resulting into geomagnetic activity, upper and lower electrojet (AU and AL) indices, provide better measurement of ground effects of eastward and westward electrojets produced by the enhanced ionospheric current in auroral oval during geomagnetic activity, Kp index is the average of the K values from all contributing observatories and plays a key role

Table 1
List of stations whose data are used together with geographic and geomagnetic coordinates.

Stations	Abbrev	Geographic latitude (°)	Geographic longitude (°)	Geomagnetic latitude (°)	Geomagnetic longitude (°)
Hermanus	HER	−34.43	19.23	−42.39	82.15
Hartebeesthoek	HBK	−25.88	27.71	−36.31	94.72
Mbour	MBO	14.38	343.03	2.06	58.24
Addis Ababa	AAE	9.03	38.77	0.16	110.47
Lerwick	LER	60.13	358.82	58.21	81.65
Eskladimur	ESK	55.32	365.80	52.89	77.76
Sodanklya	SOD	67.06	224.67	69.78	272.23
Nurmijarvi	NUR	60.51	24.66	56.75	102.48
Bangui	BAN	4.33	18.57	−5.27	90.13
L'Aquila	LAQ	42.38	13.32	36.16	87.52
Tamanrasset	TAM	22.79	5.53	9.22	78.37
Hartland	HAR	51.0	335.52	50.96	59.19
Abisko	ABI	68.36	18.82	65.11	102.31