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Research Paper

Effects of Geomagnetic Storm in the Geo-Electric Field Variations at the Dip Equatorial Latitudes in West Africa

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ABSTRACT
Data from nine African stations were used to study the effects geomagnetic storm in the geo-electric field variations at the dip equatorial latitude in West Africa. Dst index values of <-100nT and above were used to characterize stormy days. The analysis was carried out using hourly mean values of the North-South (E_x) and East-West (E_y) components of telluric electric obtained in 1992 and 1993 using telluric electric field lines operated along a meridian chain across the geomagnetic dip equator. The results show that the magnitudes of the geo-electric field response to the geomagnetic storms depend on the observational location.
KEYWORDS: *Geo-electric field, Geomagnetic Storm, West Africa, Variation, Dip Equatorial Latitude*

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I. INTRODUCTION

Solar activity which brings about space weather controls the electromagnetic and environmental conditions in the Earth's space such as magnetosphere, ionosphere and thermosphere. During space weather events, the sun continually streams out solar wind consisting of charge particles or plasma, travelling at high speeds throughout interplanetary space. Changes of currents in the Earth's magnetosphere and ionosphere during a space weather event produce temporal variations of the geomagnetic field. Currents flowing in the magnetosphere are responsible for the occurrence of geomagnetic storms and substorms (i.e. of irregular variations). The Temporal variations of the geomagnetic field are accompanied by an electric field whose horizontal component can, in extreme cases, exceed 10 V/km at the Earth's surface [12]. This electric field induced at the earth's surface known as geo-electric field is the source of electrical currents that can cause damage to transformers in the power grid and cause corrosion to pipelines. This induced electrical currents at the surface of the earth are often times termed geomagnetically induced current (GIC) in technological systems.

The effects of GICs are mostly recorded at high latitude regions as a result of variations relating to the increase in electrojets during the high ionospheric convection conditions and substorms, however, it has been established that disturbances that originate from the high-latitude ionospheric currents extends towards mid- and low latitude during magnetic storm. GICs have been reported to cause perturbation in technological structures in the mid- and low latitudes [7], [9] and [10]

The risk associated with GICs has been shown following large geomagnetic impulses such as sudden storm commencement (SSC) at low and mid latitude [6]. [1] on the bases of time derivative of geomagnetic and geo-electric fields, analysed the induction effects of the space weather events. They found that the most important induction effects during the geomagnetic storm of April 4, 1993 are associated with brisk impulses like storm sudden commencement (SSC) and solar flare effect (SFE) in the geomagnetic field variations.

The variation in geo-electric field in view of its importance in the effects of space weather on technological system has not been extensively studied; Mostly in the African region unlike the geomagnetic field. Although, few studies had been carried out which includes the works of [11], [2], [4] and [5] these works where done in the dip equatorial latitudes. These authors showed that there are diurnal variations in the geo-electric field.

In view of this lag in the geo-electric field studies in the African region, a chain of 10 electromagnetic stations were installed in the African longitudes during the French participation in the International Equatorial

Electrojet year experiment (IEEY). The Electric field measurement carried out in that experiment will be employed here to investigate the effects of geomagnetic storms in the geo-electric field variation at the dip equatorial latitude of West Africa.

II. MATERIALS AND METHOD

The data set used in this analysis consists of hourly mean values of the North-South Component (Ex) and the East-West Component (Ey) of the geo-electric field obtained from the ten geomagnetic and geo-electrical stations installed during the IEEY in Africa. These stations are located between Ivory Coast in the South and Mali in the North. These stations includes Korhogo (KOR), Koutiala (KOU), Lamto (LAM), Mopti (MOP), Nielle (NIE), San (SAN), Sikasso (SIK), Tiebissou (TIE) and Tombouctou (TOM) (Table 1)

Table 1. Geographic coordinates of the magnetic stations installed along the meridian 5°W in West Africa during the International Equatorial Electrojet Year.

Stations	Stations Code	Latitude (°N)	Longitude (°W)	Dip Latitude (°N)
Tombouctou	TOM	16.73	3.00	6.76
Mopti	MOP	14.51	4.09	4.02
San	SAN	13.24	4.88	2.45
Koutiala	KOU	12.36	5.45	1.38
Sikasso	SIK	11.34	5.71	0.12
Nielle	NIE	10.20	5.64	-1.30
Korhogo	KOR	9.34	5.43	-2.38
Katiola	KAT	8.18	5.043	-3.85
Tiebissou	TIE	7.22	5.243	-5.04
Lamto	LAM	6.23	5.02	-6.30

The data analysis started with selection of stormy days. This was done using
1hour Dst index values obtained from WDC site. The storm was characterized following [3] nomenclature. Table 2 shows the characterization.

Table 2 Nomenclature often used in classification of geomagnetic Storms (Gonzalez *et al.,* 1994)

Storm	**Minimum**	**Minimum**	**Time**
Classification	Dst (nT)	Bz (nT)	Time
Weak	-30	-3	1h
Moderate	-50	-5	2h
Intense	-100	-10	3h
Super-intense	-500	-50	>3h
Extreme	< -500	<-50	<3h

For this present study, the storms considered are storms with Dst magnitude of ≤-100nT. These intense (moderate) storms selected are seen to have three phases: initial, main and recovery phases, which began with a broad search. The main phase was defined as the maximum (least intense) Dst within the 24hrs preceding the peak. The end of the recovery phase was determined by locating the Maximum Dst within 96hrs after the peak. The Dst index profiles of the stormy days depicting a day before the storm, stormy day and the day after the storm were plotted. From the available data, the geomagnetic and geo-electric fields (E_x and E_y) profiles of those stormy days were also plotted across the ten stations and the effects of these storms were examined.

III. RESULTS AND DISCUSSION

Three geomagnetic storms have been studied within 1992 and 1993. The three geomagnetic storms considered are the geomagnetic storm of 29th December 1992, 9th March 1993 and 11th March 1993.

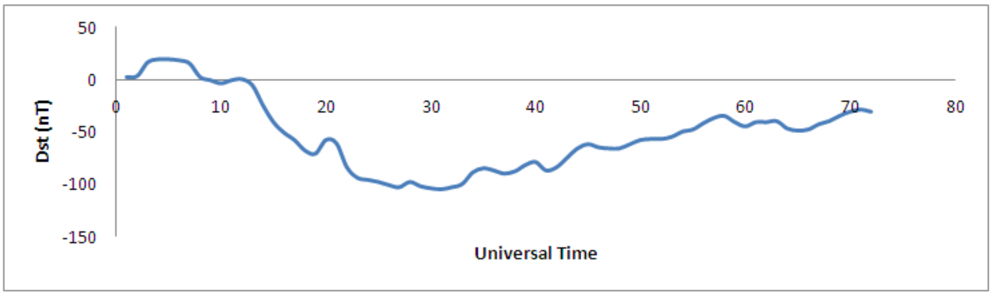

Figure 1: The Dst index from 28 to 30 December 1992. An SSC at 05:00 LT starts the process of an intense geomagnetic storm on 29th December. During the main phase of the storm, the Dst minimum value is-105nT around 31:00UT (http://wdc.kugi.kyoto-u.ac.jp/dst_final/index.html).

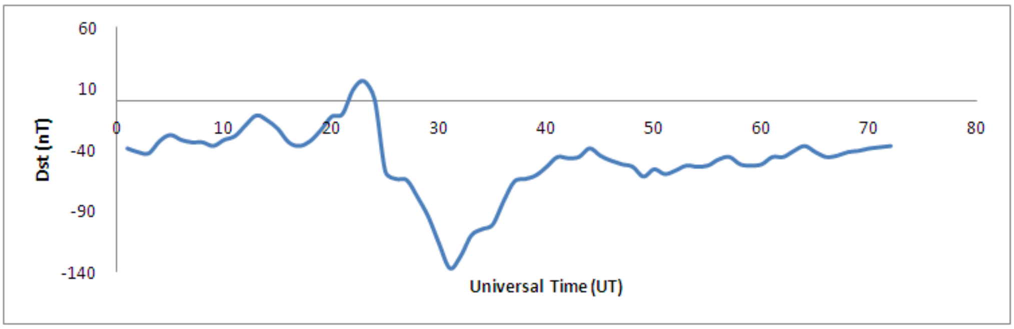

Figure 2: The Dst index from 8 to 10 February 1993. An SSC at 11:00LT starts the process of a intense geomagnetic storm on 9th March. During the main phase of the storm, the Dst minimum value is-137nT around 31:00UT. (http://wdc.kugi.kyoto-u.ac.jp/dst_final/index.html).

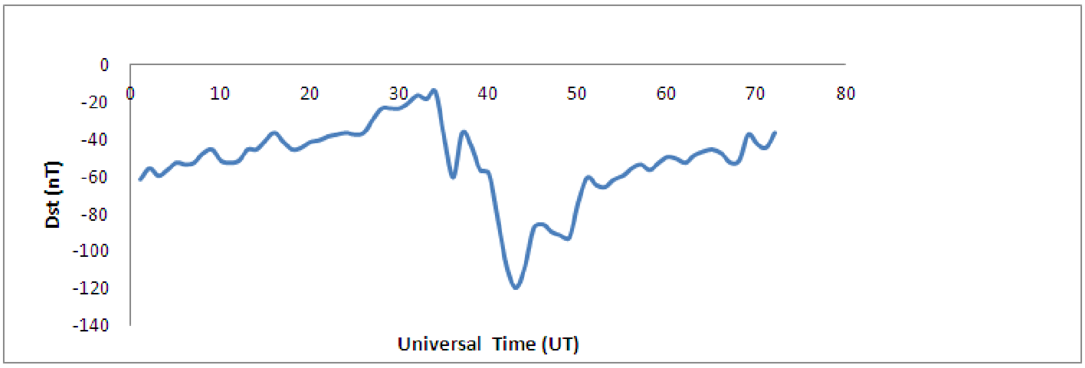

Figure 3: The Dst index from 10 to 12 February 1993. An SSC at 10:00 LT starts the process of intense geomagnetic storm on 11th March. During the main phase of the storm, the Dst minimum value is-120nT around 43:00UT. (http://wdc.kugi.kyoto-u.ac.jp/dst_final/index.html).

3.1 Geo-electric field response to the 29th December 1992, 9th and 11th March 1993 Geomagnetic Storms

The geomagnetic storms which occurred on 29th December, 1992, 9th and 11th March 1993 were an intense storm of magnitude -105nT, -137nT and -120nT respectively. Here, we examined and discussed the response of geo-electric field to these storms as follows:

3.2. 29th December 1992 geomagnetic storm

The response of the geo-electric to the intense storm that occurred on the 29th December 1992 is shown in figure 4. It could be seen from figure 4 that this storm with a maximum Dst index of -105nT at 07:00LT had a sudden storm commencement which peaked at about 05:00LT. Across the stations, the geo-electric field response to this storm can be observed at E_x = 216.5 mVkm^{-1} while E_y has no data for MOP; E_x = 280.9 mVkm^{-1} and E_y = 134 mVkm^{-1} for KOU, E_x = 107.8 mVkm^{-1} and E_y = 103.2 mVkm^{-1} for NIE E_x = 102.9 mVkm^{-1} and E_y =107.1 mVkm^{-1} for SAN.

Notice that, a Northern station MOP, farther away from the dip latitude shows stronger amplitude at E_x than those of the dip latitude such as the E_x of SAN and NIE respectively. Different lateral resistivity possibly underlies the fact that E_x has higher amplitude at MOP than SAN and NIE. Mop is a coastal town, thus the increased amplitude could be as a result of the water and possibly salt content.

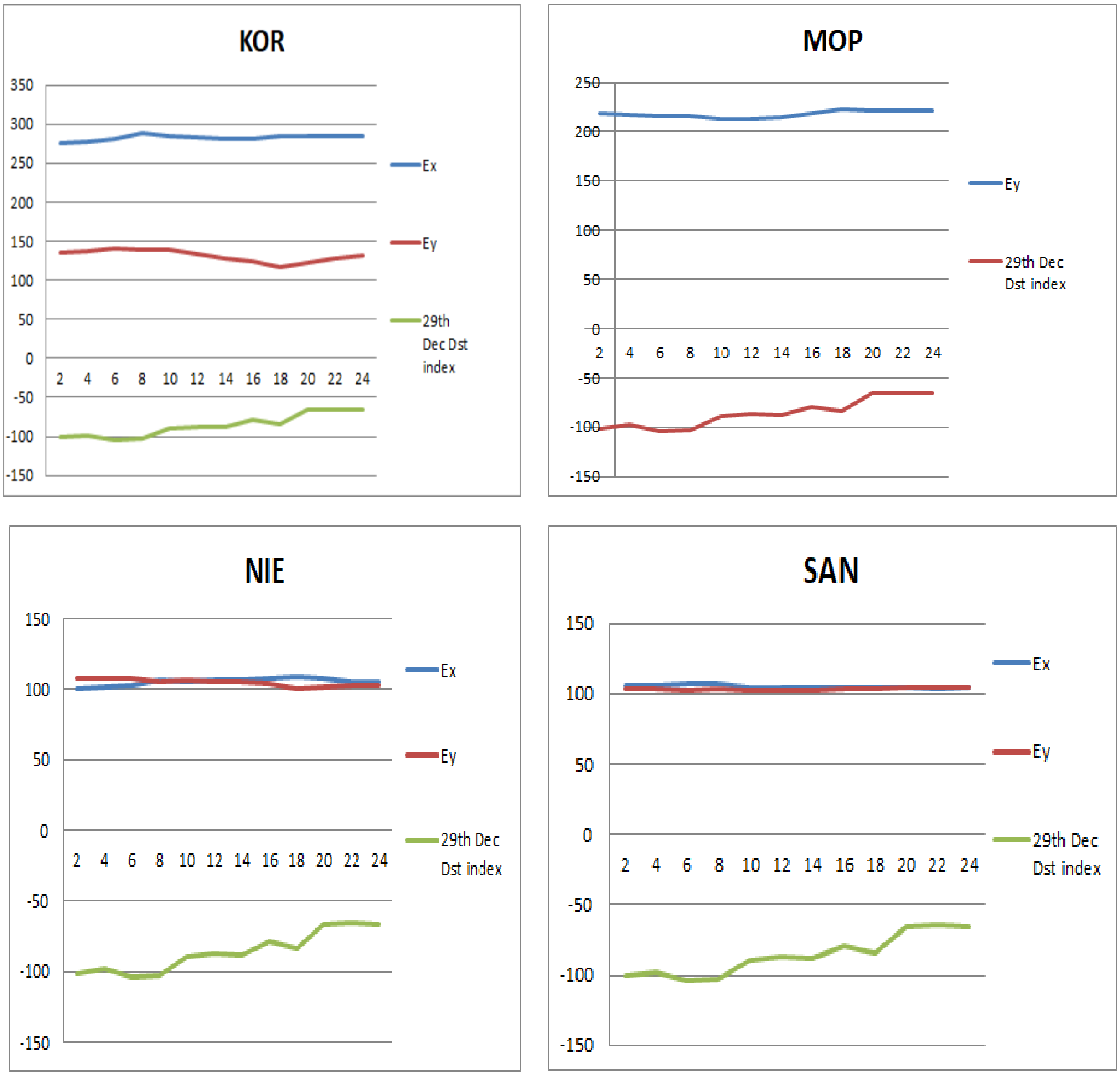

Figure 4: Geo-electric field response to 29th December 1992 storm for KOR, NIE, SAN and MOP stations

3.3. 9th March 1993 Storm

Figure 5 shows the response of geo-electric field to the storm that occurred on the 9th March 1993, the geo-electric field response to the storm that occurred around 07:00LT across Koutiala (KOU), Lamto (LAM), Mopti (TOM), Tombouctou (TOM) and Tiebissou (TIE) can be observed at E_x = 132.8 $mVkm^{-1}$ and E_y = 281.8 $mVkm^{-1}$ for TOM, E_x = 217.4 $mVkm^{-1}$ and E_y = 217.4 $mVkm^{-1}$ for MOP, E_x = 214.4 $mVkm^{-1}$ and E_y = 246.5 $mVkm^{-1}$ for KOU, E_x = 362.5 $mVkm^{-1}$ and E_y = 366.3 $mVkm^{-1}$ for TIE and E_x = 338.6 $mVkm^{-1}$ and E_y has no data for LAM

Here, a dip latitudinal station, KOU, is observed to show stronger amplitude than TOM a non-dip latitudinal station at $E_{x;}$ contrary to what is observed in the 29th December 1992 storm. This could be as a result of the equatorial electrojet current influence.

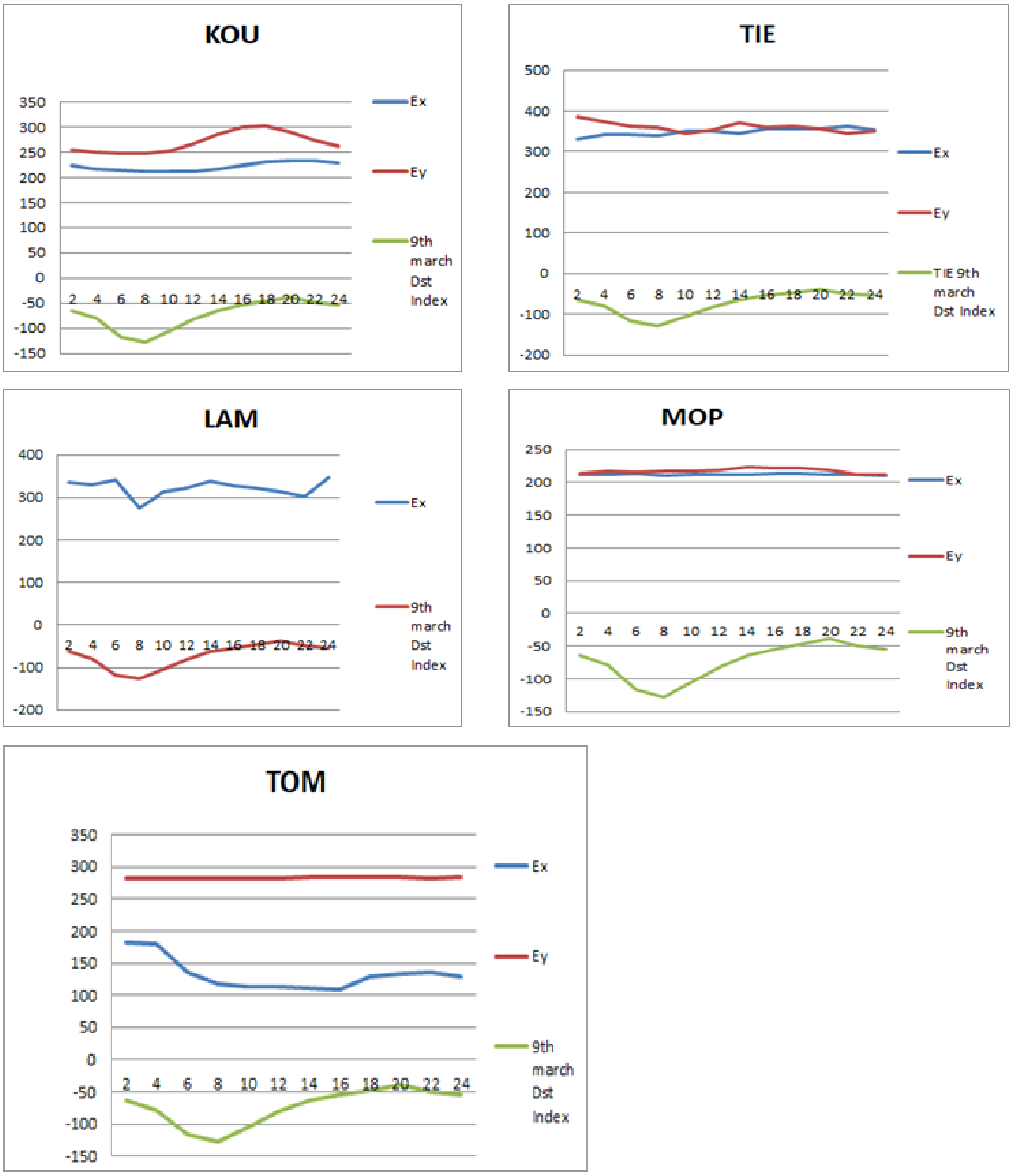

Figure 5: Geo-electric field response to 9th March 1993 storm for KOU, LAM, MOP, TOM and TIE stations

3.4. 11th March 1993 Storm

The geo-electric field response corresponding to the main phase of the last understudied storm, 11th March 1993 storm across Koutiala (KOU), Mopti (MOP), Tiebissou (TIE), and Tombouctou (TOM) stations were visibly seen at E_x = 227.1 mVkm^{-1} and E_y = 285.6 mVkm^{-1} for TOM, E_x = 221.6 mVkm^{-1} and E_y =221.6 mVkm^{-1} for MOP, E_x =219.5 mVkm^{-1} and E_y = 285.6 mVkm^{-1} for KOU, E_x = 333.2 mVkm^{-1} and E_y = 322.3 mVkm^{-1} for TIE

Here again, TOM, MOP and TIE; a non-dip latitude stations show higher amplitude than a dip-latitudinal station, KOU at E_x. There is no special latitudinal pattern maintained. A further probe into the electrical resistivity distribution in West Africa by means of magnetotelluric sounding profiles shows that stations north of the dip latitude in Mali have a high conducting anomaly [8]. These stations (TOM, MOP, SAN and KOU) are found to be located in the sedimentary basin and those south of sikasso (LAM, TIE, KAT, KOR and NIE) are situated in continental/ continental shield [11].

Figure 6 shows the reponse of geo-electric field to 11th March storm.

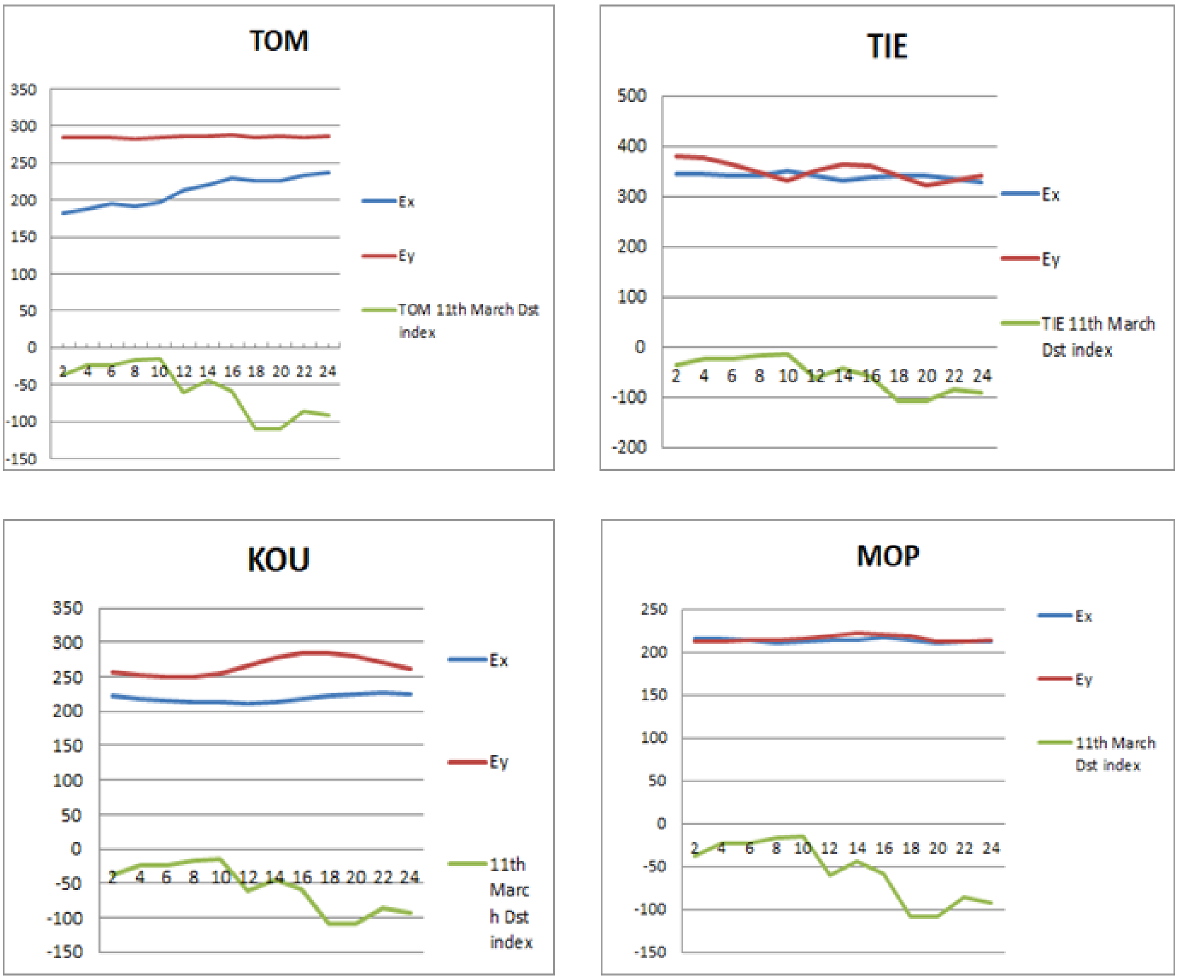

Figure 6: Geo-electric field response to 11th March 1993 storm for KOU, MOP, TIE, and TOM stations

These observations are in agreement with the work of [1]. They attributed this non-latitudinal pattern behaviour to the lateral resistivity differences from one location to another; local conditions like conductive (non-resistive) materials existing in a location play a vital role in determining the extent of electrical conduction in that location.

IV. CONCLUSION

In this work, we have studied the effects of geomagnetic storm in the geo-electric field variations at the dip equatorial latitudes in West Africa in the year 1992 and 1993. Ten stations at the low/dip latitude have been employed for this work. The following conclusions were made from the results obtained in this study.

(1) The storm effects of geomagnetic storm are more intense at the stations closer to the dip equator than those farther away especially those located in a conductive systems

(2) The magnitude of the geo-electric field response to the geomagnetic disturbances depends on the observational location.

(3) The associations of geomagnetic field and geo-electric fields does not show any latitudinal pattern/trend but observed to be dependent on the differences in the local conditions of the geomagnetic stations.

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