Characterization of the equatorial electrodynamics during the ionospheric disturbance dynamo process: observations from IEEY campaign data analysis.

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Abstract

Criteria, based on magnetic data analysis recorded during the International Equatorial Electrojet Year (IEEY) campaign (1992-1994), are used to select ionospheric disturbance dynamo events on quiet days after magnetic storms. Ground based magnetic field measurements and ionosonde data recorded in the African equatorial region, allows to characterize the magnetic and electrodynamic disturbances observed at the magnetic equator. These events present a weak auroral activity on the quiet days after the storms and amplitude decreasing of the magnetic field H component. That is due to the falling of the eastward equatorial electrojet intensity confirming the westward electric current flow which is superimposed to the regular eastward equatorial electrojet. During these events, the F2 region electron density strongly increased and we observed an upward lift of the F2 layer compared to that of the quietest day used as reference. This result is not due to the westward disturbed electric field generated confirming the large effects of the thermospheric disturbances on the equatorial F region electrodynamic parameters during these events.

1. Introduction

During a magnetic storm, there are two main physical process of disturbance that take place in the ionosphere, at planetary scale: the direct penetration of magnetospheric convection electric field [1] and the ionospheric disturbance dynamo [2]. Auroral electric currents transfer heat energy to the neutral gas via Joule heating $J.E$ (J for electric current density and E for electric field). In addition they move the neutral wind via momentum transfer by Ampere force $J \times B$ (B for geomagnetic field). Joule heating and momentum force drive thermospheric winds and pressure fields, and produce gravity waves and equatorward thermospheric winds at F region heights [3]. These thermospheric winds extend from auroral zone to mid and low latitudes with a return flow at E region altitudes around the equator. Due to the action of the Coriolis force, the southward meridional winds produce zonal westward thermospheric motion involving daytime disturbances of electric fields and currents at the equator called ionospheric disturbance dynamo [2].
We selected cases of ionospheric disturbance dynamo during two periods of storm on the basis of Dst index, auroral electrojet data and magnetic field measurements at high, mid, low and equatorial latitudes analysis to characterize the effects of this event on the equatorial electrodynamic parameters.

2. Data and method of analysis

Since the purpose of this work is to study only the ionospheric disturbance dynamo mechanism, the cases studied are selected on the basis of the following criteria. The periods of observation are mainly daytime in order to study the dynamo action in the E region. These periods are immediately after a magnetic storm during which there is a Joule heating in the auroral zone that modified thermospheric circulation and disturbed the electric fields and currents at equatorial latitudes. The period of observation must have a weak auroral activity so that there is no penetration of magnetospheric convection electric field. Dst index illustrates the development of the magnetic storm [4] and the effects of various magnetospheric current systems while the auroral indices AU and AL are used to evaluate the auroral electrojet. The horizontal H component of the magnetic field is used to estimate the intensity of the equatorial electrojet current. For each period of observation, the magnetic fluctuation due to the ionospheric disturbance dynamo mechanism is evaluated by the following equation:

$$H_{disturbance} = H - Dst \times cos(L) - S_R \quad (1)$$

where L represents the dipole latitude of the station and S_R the daily quiet variation of H. Disturbances are evaluated by comparison with reference magnetic quiet days [5]. The ionosonde data used are those of the station of Ouagadougou (12.40° N; 1.50° W; dip 5.94). The ionograms are inverted with the NHPC code [6] to compute the ionospheric parameters *foF2* and *hmF2*. The Two periods (N1 and N2) of storm selected are: period N1 (from December, 17th to 18th, 1992) and period N2 (from June, 10th to 11th, 1993). Tables 1 and 2 give respectively the geophysical context of the periods of study and the coordinates and locations of the magnetometers.

Table 1: The geophysical context of periods studied

Periods	Days	ΣKp	Auroral activity	Remark
No1	December, 17 1992	25+	Intense	Disturbed day
	December, 18 1992	16+	Very weak	Quiet day
	December, 26 1992	9+	Very weak	Reference quiet day
No2	June, 10 1993	21+	Intense (between 2000 UT and 2400 UT)	Disturbed day
	June, 11 1993	17	Very weak	Quiet day
	June, 21 1993	2+	Very weak	Reference quiet day

Table 2: Magnetometers location coordinates

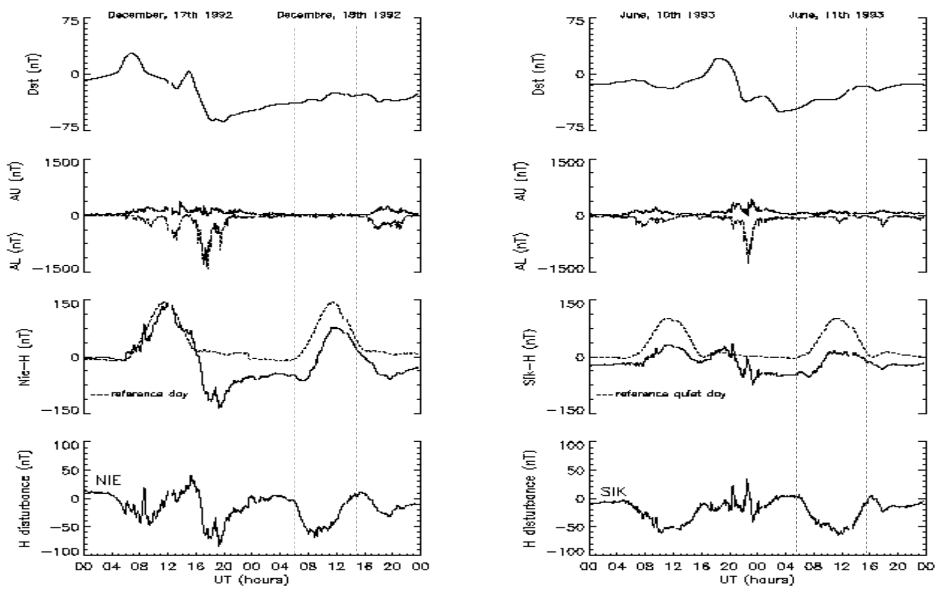
Code	Name of station	Geographic coordinates (in degree) Latitude North	/ Longitude East	Dip-latitude (in degree)
HRN	Hornsund	77.00	15.55	71.48
BJN	Bjornoya	71.32	19.20	67.51
LER	Lerwick	60.13	358.82	60.79
CLF	Chambon-la-Foret	48.03	2.26	53.50
TAM	Tamanrasset	22.79	5.53	27.44
TOM	Tombouctou	16.73	357.00	5.51
SAN	San	13.23	355.12	2.01
SIK	Sikasso	11.34	354.29	0.12
NIE	Nielle	10.20	354.36	-1.01
KOR	Korhogo	9.34	354.57	-1.88

3. Cases studies: observations

Figure 1 a-b shows the variation of the Dst, AU, AL indices and the H component recorded in the equatorial zone for N1 and N2. The Dst variations indicate the beginning of magnetic storms on December, 17th 1992 and on June, 10th 1993. During the main phases of storms, AU and AL indices show an intensification of auroral electrojets which become weaker when the recovery phase starts. On December, 18th, between 0000 UT and 1600 UT and on June, 11th, during the recovery phase, the auroral activity effects in the equatorial zone remains weak, and we clearly observe a reduction of the H component amplitude in the time intervals 0600 UT-1500 UT for December 18th and 0600 UT-1600 UT for June 11th. Variations of H disturbance in the same time interval show a negative deflection that occurs simultaneously with the decline of the auroral activity. Figure 2 a-b presents the variations of H component perturbations in the time interval 0600 UT-1600 UT from high to equatorial latitudes, respectively on December 18th and June 11th. We observe an insignificant disturbance at high and mid latitudes but a strong disturbance at low and equatorial latitudes. The ionospheric parameters NmF2 and hmF2 variations on December 18th and on June 11th are represented by figure 3 a-d. They are compared to those of the reference days in dashed line. We note an increase of the F2 region electron density in the time interval 0600 UT-1230 UT and the density becomes similar to that of the quietest day from 1230 UT to 1500 UT, on December 18th. The same observation is noted on June 11th. There is an increasing of the F2 region electron density followed by a period where it is similar to that of the quietest day. We observe an upward lift of the F2 layer in the two cases.

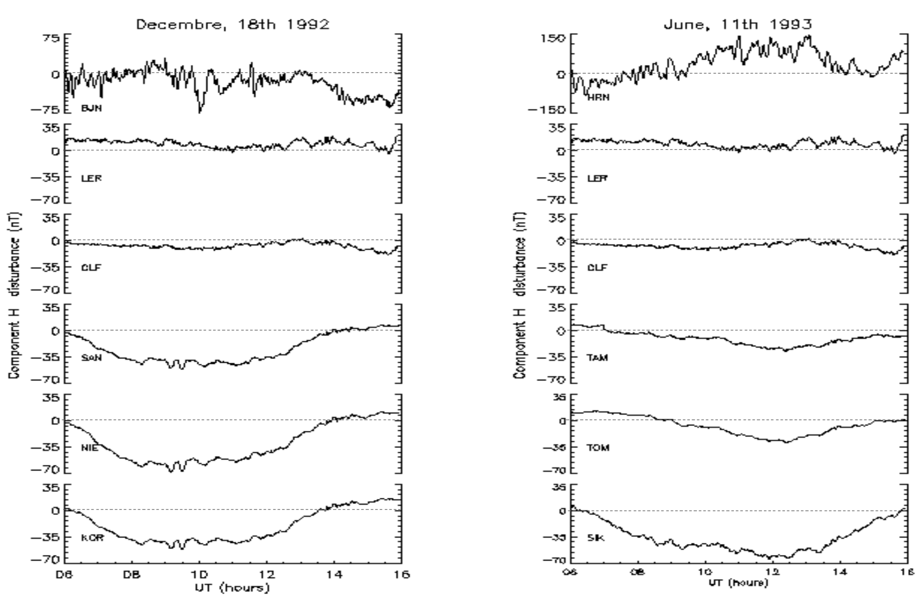
4. Discussion and Conclusion

The two periods of storm selected present the same characteristics for what concerns the Dst index variations, the AU and AL indices variations and the H component of the magnetic field variations. The decreasing of H component amplitude is due to the decreasing of the eastward equatorial electrojet intensity confirming a westward electric current flow which is superimposed to the regular eastward electric current. The attenuation of the equatorial electrojet during the quiet day following the storm is the signature of the ionospheric disturbance dynamo process, at the equator, predicted by the theory [2]. Variations of H disturbance show a southward deviation which corresponds to a westward disturbed electric field involving a westward electric current which reduces the equatorial



(a) (b)

Figure 1: Variations of Dst; AU, AL; H and H disturbance for the periods N1 (a) and N2 (b).



(a) (b)

Figure 2: Variations of H disturbance from high to equatorial latitudes, in the time interval (0600 UT-1600 UT) on December, 18th 1992 (a) and on June, 11th 1993 (b). The dashed line indicates the level zero.

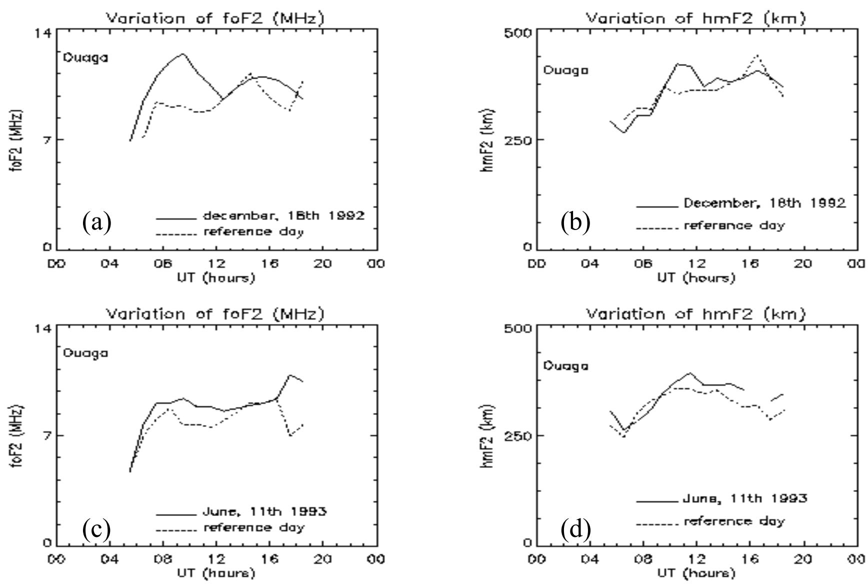


Figure 3: Diurnal variations of foF2 (a-c) and hmF2 (b-d).

electrojet. On December 18th between 0600 UT and 1500 UT and on June 11th in the time interval 0600 UT-1600 UT, we observe the same features described above for the Dst index, AU and AL indices, H component and its disturbance variations. The auroral electrojets are very weak, there is no penetration of magnetospheric convection electric field. We have only an ionospheric disturbance dynamo event in these periods. The effects of this process on F2 layer electron density at the equator correspond to an enhancement of this parameters probably due to the motion of particles toward equator by the generated thermospheric winds extend from the auroral zone to mid and low latitudes [7] at F region heights. The upward lift of the F2 layer observed during these events is not due to the westward disturbed electric field which should involve downward vertical drift and thus a fall of the F2 layer. The thermospheric disturbances could be at the origin of the uprising of the F2 layer.

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