Equatorial electric fields of ionospheric disturbance dynamo origin

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ABSTRACT. Groundbased magnetometer and ionosonde data from a selected number of stations in the 72-85° E sector are used to demonstrate that significant and persistent reductions in the strength of the equatorial electrojet, accompanied by a poor development of the equatorial ionization anomaly sometimes occur concomitant with negative ionospheric storms at midlatitudes. These events which follow geomagnetic disturbances with delays of 13-22 h are interpreted as signatures of equatorial disturbance dynamo electric fields produced by the stormtime modifications in the global thermospheric circulation due to energy inputs at high latitudes. The data also revealed that such delayed electric field disturbances do not necessarily follow enhanced geomagnetic activity even when negative ionospheric storms prevail at midlatitudes in the relevant longitude sector and masking by transient electric field perturbations is not apparent. It thus seems that not only the geomagnetic disturbance but even a disturbance in thermospheric circulation at midlatitudes is only a necessary but not a sufficient condition for the generation of disturbance dynamo electric fields in the equatorial region. Chemical composition changes at midlatitudes due to localized stirring-up of the thermosphere by disturbances such as convective travelling disturbances, long-period gravity waves, and modifications of the low latitude stormtime circulation by localized heat sources such as midnight temperature bulge are suggested as plausible causes of the evidenced absence of one-to-one correspondence between midlatitude negative ionospheric storms and equatorial disturbance dynamo electric fields.

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INTRODUCTION

The circulation of the neutral atmosphere across the earth's magnetic field under the influence of tidal winds (ionospheric wind dynamo) and the convection of magnetospheric plasma due to dynamical interactions between the solar wind and the magnetosphere (solar wind-magnetosphere dynamo) are generally considered to be the principal sources of electric fields in the ionosphere (e.g. Mozer, 1973). Recent studies provide compelling evidence for alterations in the global distribution of ionospheric currents and electric fields especially during severe geomagnetic activity conditions, by perturbations in the solar wind-magnetosphere dynamo and ionospheric wind dynamo (see Blanc and Richmond, 1980 ; Blanc, 1983 ; Fejer, 1986 and references therein). Near the dip equator, the planetary east-west electric field that drives the equatorial electrojet current, and the ionospheric characteristics that are primarily related to it (e.g. appearance of *Esq* in ionograms, vertical plasma drifts in *F*-region) are found to respond to sudden and prominent transitions in the orientation of the north-south (B_z) component of the interplanetary magnetic field, IMF (see Fejer, 1986 and references therein). These transient electric field changes are currently discussed in terms of direct penetration, right down to the dip equator, of perturbations in high latitudes electric fields due to alterations in the auroral/ring current systems or magnetospheric convection (see Fejer, 1986). The main theme of the present work is, however, not a discussion of the B_z related prompt and rapid changes in the equatorial zonal electric fields, but the delayed and rather persistent changes in them, caused by modifications in the neutral atmosphere circulation due to energy input to the high latitude thermosphere during geomagnetic disturbances i.e., through the ionospheric disturbance dynamo mechanism. The recent modeling studies show that the delayed ionospheric disturbance dynamo related electric fields can decrease and occasionally even reverse the quiet time electric field pattern in the vicinity of dip equator (Blanc and Richmond, 1980 ; Blanc, 1983). Although the earlier studies of stormtime equatorial ionosphere suggest the presence of disturbance dynamo related electric fields (see Blanc and Richmond, 1980 for a detailed discussion of the earlier results), direct experimental evidence has become available only quite recently from *F*-region vertical plasma drift measurements at Jicamarca with the incoherent scatter radar technique (Fejer *et al.*, 1983). The results of Fejer *et al.* showed that, at Jicamarca, the disturbance dynamo related electric field perturbations manifest with delays of 16-

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24 h with reference to the causative geomagnetic disturbances, and with a marked preference for the postmidnight-prenoon local time sector.

The objective of this paper is to report the findings of a specific search made for equatorial electric fields of disturbance dynamo origin using groundbased magnetometer and ionosonde data. To the best of knowledge of the author, no such concerted effort has been made hitherto, although the feasibility of using magnetometer data for studying disturbance dynamo electric fields is known and, in fact, has been suggested in the literature (Blanc and Richmond, 1980). The only sort of exception is the observation by Tanaka (1981) of a reduction in the strength of the equatorial ionization anomaly simultaneous with the negative phase of an ionospheric storm at midlatitudes (indicative of composition changes due to modifications in global thermospheric circulation) on 10 April 1980 in the Japanese sector. Tanaka did not however investigate the origin of the poor development of the ionization anomaly, i.e. whether it is a consequence of weakening of the « fountain » mechanism (see Rajaram, 1977) due to disturbance dynamo electric fields or an effect of converging winds on the equator (Burge *et al.*, 1973 ; Rishbeth, 1975). The motivation for the present effort is that, if the outcome is positive, the extensive data from the global networks of magnetometers and ionosondes can judiciously and profitably be used subsequently to derive the characteristics of the disturbance dynamo electric fields. This is particularly so because the incoherent scatter radar facility, though highly resourceful for the study of electric field disturbances, is available only at a very few equatorial locations widely separated in longitude. It is necessary to emphasize at this juncture that, unlike the incoherent scatter radar technique which enables continuous monitoring of *E*- and *F*-region plasma drifts (and hence zonal electric field), the magnetometer data permit assessment of the electric fields only during daytime when the ionospheric conductivity and currents are appreciable. In view of this inherent and severe limitation of the experimental data base used, we have adopted a strategy slightly different from that of Fejer *et al.* (1983) of examining selected periods when a large magnetic disturbance was followed by a quiet time interval. It is widely accepted that the marked storm daytime depressions in f_oF_2 at midlatitude locations are ionospheric manifestations of thermospheric composition changes brought about by modifications in the global thermospheric circulation due to stormtime heating at high latitudes (e.g. Chandra and Herman, 1969 ; Matuura, 1972 ; Rishbeth, 1975 ; Park and Meng, 1976 ; Sastri and Titheridge, 1977 ; Prolss, 1977 ; Mayr *et al.*, 1978 ; Prolss, 1981). We have therefore examined the equatorial magnetometer and ionosonde data only for specific stormtime intervals with a prominent negative phase during daytime at midlatitude stations in the longitude zone of interest. Since the latitudinal extension of the thermospheric compositional disturbances is known to depend on season (e.g. Prolss, 1977 ; 1981), and since the spatial extent of some of the ionospheric storms can sometimes be fairly limited (e.g. Kane, 1973), the above selection procedure ensured that not only the geomagnetic disturbance but also the one in thermospheric chemical composition (and hence in global circulation) did occur in the relevant longitude sector.

OBSERVATIONS

The present study is based on the published data of magnetometer and ionosonde experiments at a selected number of stations in the 72-85° E longitude sector (Indian zone). The stations, the details of which are given in table 1, are carefully chosen so that they provide the required data in optimum inspite of their number being small. Of the two magnetometer stations, Trivandrum is located almost on the axis of the equatorial electrojet in the Indian zone, while Alibag is well outside the influence of the electrojet. Simultaneous data from these two stations are thus well suited (and hence widely used) for estimating the strength of the equatorial electrojet, particularly during stormtime conditions when the groundlevel magnetic variations receive contributions not only from overhead currents in the ionospheric dynamo region but also from distant currents associated with magnetospheric sources (e.g. Rastogi and Patel, 1975 ; Bhargava *et al.*, 1980). As regards the ionosonde stations, Tomsk, Karaganda and Alma-Ata provide the key information on negative ionospheric storms (as seen in f_oF_2) at highmid- to midlatitude stations in the Indian sector. Of the two ionosonde stations in the equatorial region, Kodaikanal is usually near the trough of the ionization anomaly while Ahmedabad is around the crest of the anomaly.

Table 1
Details of stations

Stations	Symbol	Geographic coordinates Latitude	Longitude	Geomagnetic Latitude
Ionosonde		° ′	° ′	° ′
Tomsk	TK	56 28 N	84 56 E	45 55 N
Karaganda	KA	49 49 N	73 05 E	40 19 N
Alma-Ata	AL	45 15 N	76 55 E	33 25 N
Ahmedabad	AH	23 01 N	72 36 E	14 01 N
Kodaikanal	KO	10 14 N	77 29 E	00 44 N
Magnetometer				
Alibag	AL	18 38 N	72 52 E	09 26 N
Trivandrum	TR	8 29 N	76 57 E	00 28 S

Adequate information on changes in the development of the anomaly in response to electric field disturbances can thus be derived from f_oF_2 data of these two stations.

Careful scrutiny of f_oF_2 data of Tomsk, Karaganda and Alma-Ata for the 8-yr period from 1966 through 1973 showed the occurrence of 16 prominent negative ionospheric storm days (decrease of f_oF_2 from the monthly mean > 15 % for most part of daytime) at the three stations. The condition of simultaneity of the negative storm phase at the three stations is imposed to ensure that the causative disturbance in thermospheric composition extended at least as far as midlatitudes. The negative ionospheric storm days thus selected pertain to quiet/moderate levels of geomagnetic activity and were all preceded by moderate/severe geomagnetic disturbances (AE_{max} 565-1366 nT). 10 out of the 16 events analysed here correspond to local summer months and 6 to equinoxes. The conspicuous absence of local winter events in our data sample reflects the well known confinement to high latitudes of the thermospheric composition disturbances in the winter solstice (e.g. Prolss, 1976 ; 1977 ; 1981).

Examination of the diurnal profiles of the equatorial electrojet strength and the patterns of diurnal development of the equatorial anomaly showed unambiguous signatures of disturbance dynamo electric fields concomitant with midlatitude negative ionospheric storms in 6 out of the 16 cases studied here. The disturbance dynamo electric fields are characterised by long-lived reductions in the electrojet strength (for most part of daytime) accompanied by a poor development of the equatorial anomaly, and consistently occurred during the recovery phase of the causative geomagnetic disturbances/storms. Figure 1 illustrates a representative example of the electric field perturbations evidenced in our magnetometer and ionosonde data, which we consider as signatures of disturbance dynamo related electric fields. Shown in the figure from the bottom are the temporal profiles, during the interval 21-23 May 1968, of the north-south (B_z) component of the interplanetary magnetic field (IMF), the auroral electrojet indices, AU and AL and the equatorial D_{st} index. The middle two panels depict the diurnal profiles of the difference in H-field between Trivandrum and Alibag, $H_T - H_A$ (a measure of the electrojet strength) and its deviation from the average S_q pattern of the month $\Delta(H_T - H_A)$. The diurnal variation of f_oF_2 at Tomsk (TK), Ahmedabad (AH) and Kodaikanal (KO) are shown in the top two panels of the figure (solid/open circles) along with the monthly mean patterns (solid/dashed lines). The temporal profiles of f_oF_2 at Ahmedabad and Kodaikanal are accommodated in one panel and drawn to a common scale to facilitate inference of changes in the ionization anomaly through ready comparison of absolute values of the parameter at the two stations. As the temporal patterns of variation of f_oF_2 at Karaganda and Alma-Ata are essentially the same as those of Tomsk, they are not shown in figure 1 to avoid repetition.

On 21 May, 1968 a moderate geomagnetic disturbance started around 17 h LT (75° E) due to an obvious

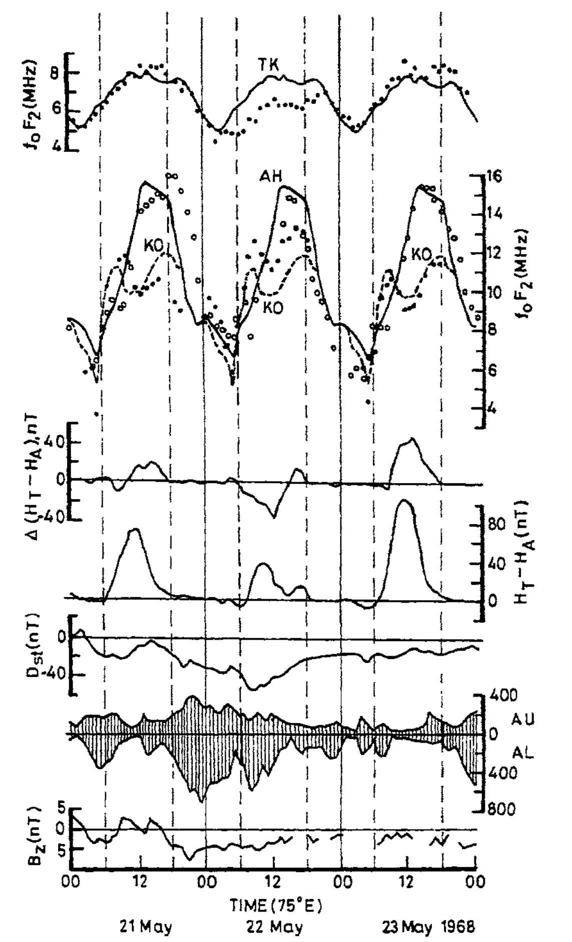

Figure 1

Time histories for 21-23 May 1968 of B_z component of interplanetary magnetic field, auroral electrojet indices AU and AL, equatorial D_{st} index, difference of H-field between Trivandrum and Alibag, $H_T - H_A$ (a measure of equatorial electrojet strength) and its deviation from the average quiet day pattern of the month. The diurnal patterns of f_oF_2 at Ahmedabad and Kodaikanal located around the crest and trough positions of the equatorial ionisation anomaly respectively in the Indian sector are also shown. The topmost panel shows the diurnal pattern of f_oF_2 at the high-midlatitude station, Tomsk in the Indian sector. The solid/dashed lines of f_oF_2 plots represent the monthly mean diurnal patterns at the respective stations. The vertical dashed lines indicate the sunrise and sunset times.

southward turning of B_z and the maximum in AE index of 1020 nT was reached around 00 h LT on 22 May. The disturbance subsided by 18 h LT on 22 May and the geomagnetic conditions remained more or less quiet over the next 24 h. During the recovery phase of the geomagnetic disturbance on 22 May (see plot of D_{st} in fig. 1), a prominent negative ionospheric storm phase prevailed at midlatitudes during daytime in the Indian sector (see $f_0 F_2$ behaviour at Tomsk, TK in fig. 1), indicating the prevalence of composition changes brought about by stormtime circulation to midlatitudes. The diurnal profiles of $H_T - H_A$ and $\Delta(H_T - H_A)$ of figure 1 show that although the equatorial electrojet strength exhibited a normal development and decay during daytime on 22 May, it also underwent an obvious reduction practically throughout daytime, when compared to adjacent days as well as the average quiet day pattern of the month. The persistent reduction in the electrojet strength could not be due to penetration electric fields not only because of the time scale of its manifestation, but also because there were no rapid and prominent swings in B_z during the time interval of the reduction in the electrojet strength, as may be seen from the B_z plot of figure 1 (the gap in B_z data prior to local sunset does not vitiate the inference). The time delay of the onset of the reduction in electrojet strength with reference to the geomagnetic disturbance on 21 May, is about 13 h, and this has to be rather an upper limit in view of the ineffectiveness of magnetometer data to monitor electric field disturbances of ionospheric origin during nighttime. It is to be mentioned here that the values of $h'F$ (the minimum virtual height of bottomside F-region that is widely taken to represent the height of bottomside F-region during nighttime) at Kodaikanal were quite close to the monthly mean values in the presunrise period on 22 May, suggesting the absence of any net electric field disturbance during that time (since the disturbance dynamo electric fields usually are opposite in sense to the normal fields, $h'F$ values are to be much higher than normal if an eastward electric field disturbance was already operative). As regards the latitudinal distribution of equatorial F-region plasma is concerned, the monthly mean diurnal patterns of f_oF_2 at Ahmedabad and Kodaikanal shown in figure 1, clearly demonstrate the usual development of the ionization anomaly just before noon and its sustenance will into the post-sunset hours, with higher values of f_oF_2 at Ahmedabad (crest of the anomaly) than at Kodaikanal (trough of the anomaly). A similar pattern was evident on 21 and 23 May as can be seen from figure 1. In contrast, on 22 May, f_oF_2 values at Kodaikanal were well above the monthly mean values during daytime, while at Ahmedabad they were well below. In fact, f_oF_2 values at these two stations were more or less the same around 18 h LT. A poor development of the ionization anomaly is thus evident which further corroborates the persistent reduction in the electrojet strength inferred from magnetic variations.

To substantiate the genuineness of our identification of the disturbance dynamo electric fields at equatorial latitudes using magnetometer and ionosonde data, the average properties of the various geophysical parameters discussed above are computed for the 6 such events in our data sample using the superposed epoch analysis technique. The day with the negative ionospheric storm effect at midlatitudes is taken as the key day for the statistical analysis. The result depicted in figure 2 demonstrates the features evidenced in individual case studies detailed earlier namely, the long-lived reduction in electrojet strength and a poor development of the ionization anomaly during daytime, in close temporal association with the negative ionospheric storm phase at midlatitudes. The average time delay between the apparent manifestation of disturbance dynamo electric fields and geomagnetic disturbance is about 18 h and this we regard as a sort of upper limit due to reasons mentioned earlier.

The present study also revealed the absence sometimes of readily identifiable signatures of disturbance dynamo electric fields near the dip equator, even when negative ionospheric storms did prevail at midlatitudes in the relevant longitude sector. The

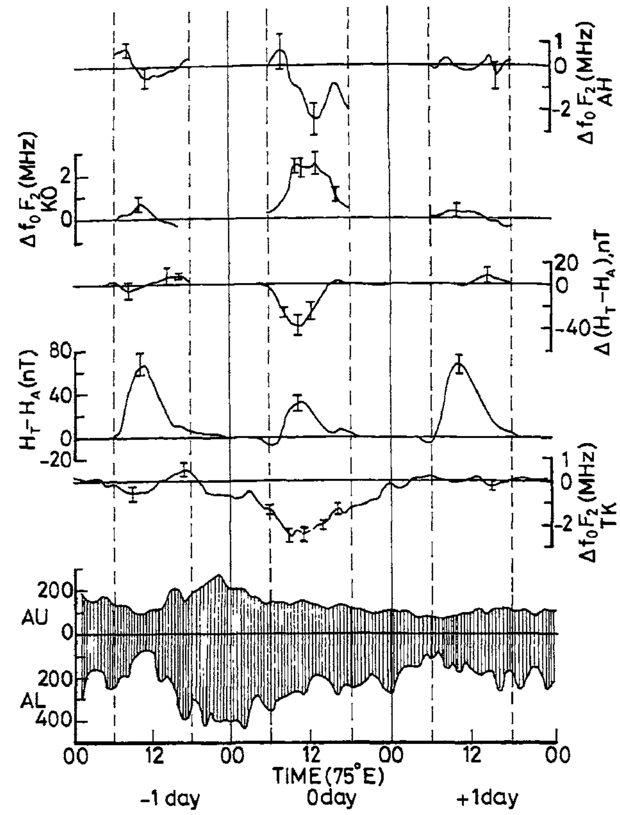

Figure 2

Average temporal profiles of AU and AL, the deviation from monthly mean of f_oF_2 at Tomsk, Ahmedabad and Kodaikanal, H_T-H_A and $\Delta(H_T$-$H_A)$ for the six cases, with disturbance dynamo electric field perturbations in the equatorial region. The average patterns of the various parameters are computed with the superposed epoch analysis technique by taking the day with the negative ionospheric storm phase in f_oF_2 at Tomsk as the key day. The vertical bars indicate the standard errors in the data.

absence of a one-to-one correspondence between geomagnetic disturbances and equatorial dynamo electric fields was also found earlier by Fejer *et al.* (1983). They have attributed this feature to the longitudinal structure of the disturbance at high latitudes and/or severity of the geomagnetic disturbance (and hence the extension to middle and low latitudes of the thermospheric disturbance). The results of our study, however, do not support this point of view because the negative ionospheric storm phase did prevail at high mid- to midlatitude stations in the narrow longitude sector we considered. Besides, the range of the degree of severity of the geomagnetic storms/disturbances (as seen in AE index) which did not result in discernible perturbations in the equatorial zonal electric fields is more or less the same as those that did so in our data sample. The range of AE_{max} for the former group of storms is 725-1112 nT while it is 742-1366 nT for the latter group. Masking by transient electric field perturbations due to other physical mechanisms such as direct penetration electric fields (see Fejer, 1984), local wind effects (e.g. Reddy and Devasia, 1981 ; Raghava Rao and Ananda Rao, 1980) and variability in the ionization distribution profile in the local dynamo region (Stenning, 1977) could, of course, partly be responsible for the absence or difficulty in recognizing the disturbance dynamo electric field patterns. Such contamination effects are, in fact, evidenced in 6 out of the 16 cases

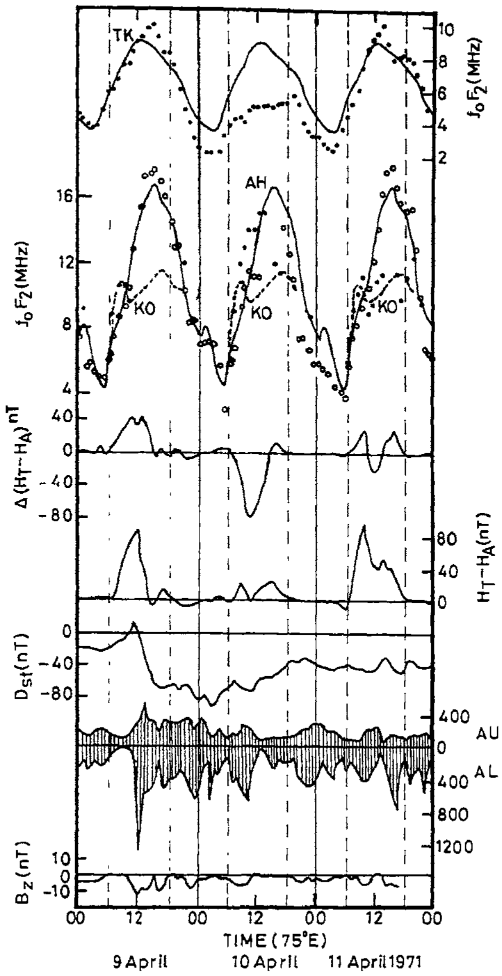

Figure 3
Same as in figure 1 *but for the period* 9-11 *April* 1971.

we examined here and a representative example of which is illustrated in figure 3. The data in figure 3 which pertain to the interval 9-11 April, 1971 are presented in the same format as that of figure 1. A severe geomagnetic disturbance characterised by a series of substorms began around 11 h LT on 9 April, 1971 and prevailed till about 09 h LT on 12 April, 1971. At the high-midlatitude station, Tomsk, f_oF_2 values which were close to the average pattern before the onset of the geomagnetic disturbance on 9 April, showed a short positive phase within a few hours of its initiation and went below the average values thereafter. The remarkable response of midlatitude ionosphere to this geomagnetic disturbance is the significant negative phase that occurred during daytime on 10 April in the Indian sector. This prominent midlatitude negative ionospheric storm occurred during the recovery phase of the causative geomagnetic storm as may be seen from the D_{st} profile in figure 3. At equatorial latitudes, the diurnal profile of the electrojet strength showed considerable distortion during the entire interval 9-11 April, 1971 as can be seen from the plot of $H_T - H_A$ in figure 3. But the most notable feature is the marked inhibition of the usual build-up and decay of the electrojet during most part of daytime on 10 April, 1971 and the associated poor development of the ionization anomaly, in close temporal association with the negative phase of the ionospheric storm at midlatitudes (see f_oF_2 plots of fig. 3). We believe that the anomalous diurnal pattern of the electrojet on 10 April, 1971 is due to the combined effects of disturbance dynamo electric fields and transient perturbations due to other physical processes. The noontime distortion of the electrojet profile (a sharp reduction prior to noon and its subsequent recovery) does not seem to be related to direct penetration electric fields associated with rapid changes in magnetospheric convection or in high latitude current systems. For example, the abrupt cessation of substorm activity around 11 h LT due to a northward turning of B_z is expected, as per the present understanding (see Fejer, 1986), to result in a negative effect or reduction in electrojet strength, while what is actually evident is the opposite as can be seen from figure 3. Perturbations due to variability either of the wind field or ionization distribution in the local dynamo region may be the cause of the noontime distortion of the electrojet diurnal pattern on 10 April, 1971.

We found no evidence whatsoever for disturbance dynamo electric field patterns in the remaining 4 events although masking effects due to other physical mechanisms were not apparent. The data pertaining to the interval 28-30 April 1971 presented in figure 4, in the same format as that of figure 1, is an example of this subset of interesting cases. A fairly isolated geomagnetic disturbance of moderate strength (AE_{max}

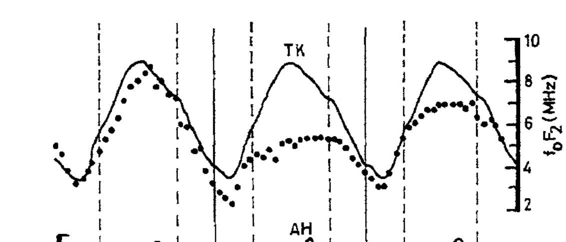

Figure 4
Same as in figure 1 *but for the period* 28-30 *April* 1971.

of constituent substorms ranged from 500 to 750 nT) began prior to local sunrise on 28 April and subsided rather abruptly just before local midnight on the same day. Unusually quiet geomagnetic conditions prevailed over the next 24 h as can be seen from the temporal variation of the auroral electrojet indices, AU and AL shown in figure 4. The equatorial D_{st} index showed the absence of a distinct recovery phase for the geomagnetic disturbance on 29 April and this characteristic feature in the temporal profile of D_{st} is consistently seen in the other 3 cases of this type in our data sample (in contrast, in the 6 events when the geomagnetic storms were followed by midlatitude negative ionospheric storms and equatorial disturbance dynamo electric fields, the latter occurred during the recovery phase of the storms as may be seen from the example illustrated in fig. 1). The f_oF_2 values at Tomsk nevertheless show a prominent negative ionospheric storm phase during day time on 29 April, which persisted on 30 April also but with a reduced amplitude. Based on the work of Fejer *et al.* (1983) and the events discussed in the previous sections, one would expect to see disturbance dynamo effects at equatorial latitudes on 29 April, and the identification of which is to be easier and unambiguous because of the very quiet geomagnetic conditions and the steady nature of the B_z component of IMF. Contrary to expectations, the development patterns of the electrojet strength and of the ionization anomaly do not indicate the presence of any significant perturbations on 29 April when compared to adjacent days, as can be seen from figure 4.

DISCUSSION

The positive and satisfying outcome of the present effort is that the manifestations of the delayed perturbations in the equatorial east-west electric field due to geomagnetic activity related modifications in the thermospheric global circulation can be identified under favourable conditions, even in experimental data from groundbased magnetometers and ionosondes which give only indirect information on electric fields. Though the time delay between the energy inputs to the high latitude thermosphere and the onset of changes in the equatorial east-west electric field due to ionospheric disturbance dynamo could not precisely be determined from magnetometer data, the upper limit of the delay is found to be 13-22 h in our sample. These delay times are in reasonable agreement with the values of 16-24 h derived by Fejer *et al.* (1983) from direct electric field measurements with the VHF radar technique at Jicamarca.

That some geomagnetic storms do not generate detectable patterns of equatorial disturbance dynamo electric fields even though they result in negative ionospheric storms at midlatitudes in the same longitude sector is a principal finding of the present study and has not been reported so far. Fejer *et al.* (1983) did study earlier the relationship between equatorial disturbance dynamo electric fields and midlatitude ionospheric storms in the American sector (75° W), but they reported to have found a disturbance dynamo pattern whenever a negative storm occurred at midlatitudes in the same longitude. This result enabled them to suggest that the longitudinal structure of the high latitude disturbance determines the location of occurrence of the equatorial electric field perturbations. The results of our study clearly demonstrate that exceptions to this do sometimes occur. We consider here two plausible scenarios for an essentially qualitative explanation of this finding. Firstly, though the prevailing consensus that negative F-layer storm effects at midlatitudes are due to photochemical processes (increase in chemical loss due to enhancement in molecular to atomic concentration ratio) is not disputed or not yet disproved, the fundamental assumption we made that they are due to composition changes brought about by stormtime circulation may not necessarily be valid all the time. This is because the required chemical composition changes can also be caused by local mechanisms, where in the needed « molecule enriched air » at F-region altitudes is supplied locally from the lower atmosphere rather than physically transported by storm circulation from auroral latitudes (see Rishbeth *et al.*, 1987, and references therein). The very recent numerical modelling work of Rishbeth *et al.* (1987) in fact casts some doubt on the theory that midlatitude negative F-layer storms are due to composition changes induced by dynamical processes originating at high latitudes. It is plausible therefore that the midlatitude negative ionosphere storms without discernible equatorial disturbance dynamo electric fields in our data sample are due to composition changes originating from mechanisms other than stormtime circulation. Alternatively, localised phenomena could sometimes render the low latitude circulation (and hence the equatorial electric field patterns) complex and rather different from the one that would prevail if stormtime heating in the high latitudes were only to be operative. Two potential candidate phenomena are the quasi-permanent midnight temperature bulge in the equatorial thermosphere and the transient energy inputs at equatorial latitudes during geomagnetic storm conditions. The midnight temperature bulge which is interpreted as due to the interaction between upward propagating tides and ion drag effects is known to exhibit marked variability as regards its amplitude and location, and so also the winds associated with it (e.g. Spencer *et al.*, 1979 ; Mayr *et al.*, 1979). It can therefore significantly influence the circulation at low and equatorial latitudes by superposing its own wind systems on that due to heating sources at high latitudes ; and this modification of the circulation is found to be quite prominent during disturbed geomagnetic conditions (Herrero and Meriwether, 1980). The other source is the localised enhancements in neutral gas temperature at equatorial locations which are found to occur during day as well as nighttime, and usually under stormtime conditions (Biondi and Sipler, 1985 ; Biondi and Meriwether, 1985 ; Gross, 1985). The nature and location of the source(s) of these heating events are obscure at the moment. It is rather difficult to envisage the details of the modified circulation due to these two phenomena and the associated equatorial electric field patterns, because most of the circulation models do not include them (e.g. Dickinson *et al.*, 1977). It is pertinent to remark here that the disturbance dynamo electric field patterns were also computed earlier by Blanc and Richmond (1980) with Joule heating in auroral oval as the sole driving mechanism of the disturbance winds. Just like the longitude structure of the thermospheric disturbance, the strength of the causative geomagnetic storm does not seem to govern the extension to middle and low latitudes of the thermospheric disturbance, and hence the occurrence of equatorial disturbance dynamo effects as mentioned earlier. The modelling work of Rishbeth *et al.* (1987) indeed showed that the injection of energy inputs to the auroral oval leads to the setting up of storm circulation as expected, but the composition changes that cause negative *F*-layer storms spread only a few degrees from the source region, and that further increase of energy inputs to the oval would not lead to more widespread changes in composition as is usually believed. According to them the only effective way of causing composition changes at midlatitudes through the storm circulation is to introduce energy inputs well equatorward of the auroral oval, perhaps even at middle and low latitudes — a point of view in line with ours as mentioned earlier.

CONCLUSIONS

It is demonstrated that the groundbased magnetometer and ionosonde data at equatorial latitudes can be used for the identification of electric field perturbations of ionospheric disturbance dynamo origin, if analysed with simultaneous ionosonde data at midlatitudes in the same longitude sector, which provide information on the thermospheric composition changes brought about by stormtime circulation through the classical negative F_2-layer storm phase. The results obtained here following this strategy coupled with those from the earlier work of Fejer *et al.* (1983) provide unambiguous evidence for the prevalence of disturbance dynamo electric fields in the equatorial region in the wake of some geomagnetic storms. The present study brought to light the absence of discernible patterns of equatorial disturbance dynamo electric fields after some geomagnetic storms eventhough they did cause prominent negative ionospheric storm effects at midlatitudes in the same longitude sector. In all such situations a distinct recovery phase of the causative storm was not seen in the temporal profiles of D_{st} index, the implications of which as regards the manifestation of equatorial disturbance dynamo electric fields are not clear to us at the moment. We suggest that the occurrence of midlatitude negative ionospheric storms without simultaneous disturbance dynamo electric fields near the dip equator is due to the modification of low latitude stormtime circulation by winds associated with localised heat sources like the midnight temperature bulge. Alternatively, the chemical composition changes generally considered to be responsible for negative ionospheric storms at midlatitudes may be caused by local mechanisms rather than stormtime circulation set up by auroral heating. Further work, both theoretical and experimental, therefore needs to be done to gain an indepth understanding of the physical mechanisms governing the generation and manifestation of disturbance dynamo electric fields in the equatorial regions. On the theoretical side, electric field calculations are to be made with stormtime circulation models including such features as heat sources not only at high latitudes but also at low latitudes and their spatial and temporal distributions. On the experimental side, detailed information is required on the dynamics of the equatorial and low latitude thermosphere simultaneous with that on plasma dynamics.

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