Simulation of electric field and current during the 11 June 1993 disturbance dynamo event: Comparison with the observations

To cite this version:

HAL Id: hal-00966445
http://hal.upmc.fr/hal-00966445
Submitted on 1 Apr 2014

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Simulation of electric field and current during the 11 June 1993 disturbance dynamo event: Comparison with the observations


Received 1 March 2010; revised 6 July 2010; accepted 2 August 2010; published 9 November 2010.

[1] The ionospheric disturbance dynamo signature in geomagnetic variations is investigated using the National Center for Atmospheric Research Thermosphere-Ionosphere-Electrodynamics General Circulation Model. The model results are tested against reference magnetically quiet time observations on 21 June 1993, and disturbance effects were observed on 11 June 1993. The model qualitatively reproduces the observed diurnal and latitude variations of the geomagnetic horizontal intensity and declination for the reference quiet day in midlatitude and low-latitude regions but underestimates their amplitudes. The patterns of the disturbance dynamo signature and its source “anti-Sq” current system are well reproduced in the Northern Hemisphere. However, the model significantly underestimates the amplitude of disturbance dynamo effects when compared with observations. Furthermore, the largest simulated disturbances occur at different local times than the observations. The discrepancies suggest that the assumed high-latitude storm time energy inputs in the model were not quantitatively accurate for this storm.

Citation: Zaka, K. Z., et al. (2010), Simulation of electric field and current during the 11 June 1993 disturbance dynamo event: Comparison with the observations, J. Geophys. Res., 115, A11307, doi:10.1029/2010JA015417.

1. Introduction

[2] During high-geomagnetic activity periods, disturbance winds from high-latitude regions may influence the low-latitude ionosphere. The disturbance wind dynamo and its influences in midlatitudes and low latitudes were first investigated by Blanc and Richmond [1980] and Spiro et al. [1988]. These dynamo effects have been associated with midlatitude winds driven by the high-latitude Joule heating and with fossil winds accelerated by strong ion convection in the auroral regions. Blanc and Richmond [1980] proposed the ionospheric disturbance dynamo mechanism to explain electric field disturbances observed at the end of magnetic storms. These electric field disturbances are assumed to be due to the disturbed thermospheric wind actions [Fejer et al., 1983; Fejer and Scherliess, 1995; Fejer, 2002; Sasri, 1988; Fambitakoye et al., 1990; Mazaudier and Venkateswaran, 1990]. Richmond et al. [2003] studied ionospheric electric field disturbances at midlatitudes and low latitudes using the Magnetosphere-Thermosphere-Ionosphere Electrodynamics General Circulation Model (MTIEGCM) [Peymirat et al., 1998]. They pointed out that three components of comparable importance can be associated with low-latitude ionospheric electric fields during disturbances, namely, dynamo effects of global tidal winds; direct penetration of polar cap electric fields directly to the magnetic equator; and dynamo effects of disturbance winds caused by high-latitude Joule heating.

[3] The influence of geomagnetic activity on midlatitude and low-latitude thermospheric winds and ionospheric electric field has been investigated using the National Center for Atmospheric Research (NCAR) Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) by Huang et al. [2005]. The model results showed that, when the geomagnetic activity ceases, zonal disturbance winds can last for many days in the postrecovery period, while the meridional disturbance winds vanish more rapidly. These results are in accordance with the changes in the thermospheric circulation [Testud and Vasseur, 1969; Richmond and Roble, 1979; Mazaudier et al., 1985], which lead to disturbances of electric fields and currents at midlatitudes and low latitudes [Volland and Mayr, 1971; Testud et al., 1975; Blanc, 1978]. However, the ionospheric disturbance dynamo effects observed at midlatitudes and low latitudes through measurements of electric fields and currents [Fejer et al., 1983; Mazaudier and Venkateswaran, 1990; Fejer and Scherliess, 1995; Abdu et al., 1997] have not yet been fully reproduced by models.

[4] In the present study, we use the NCAR TIE-GCM to investigate the effects of disturbance winds on the electric field and current in the midlatitude and low-latitude ionosphere during the disturbance dynamo (Ddyn) event on 11 June 1993 [Zaka et al., 2009]. To that end, the observed magnetic variations are compared with the model results. In fact, electric current simulations at midlatitudes and low latitudes with the TIE-GCM have not yet been presented for disturbed conditions. Using the TIE-GCM to simulate the
equatorial electrojet (EEJ) magnetic perturbations, Doumbia et al. [2007] focused their study on magnetically quiet periods only. Furthermore, the previous simulations performed by Richmond et al. [2003] did not assess the capability of the model to reproduce the current circulation associated with the ionospheric disturbance dynamo mechanism at midlatitudes and low latitudes. By comparing the simulated and observed geomagnetic perturbations and by examining the TIE-GCM winds in the dynamo region that helped create these perturbations, we can gain information about how well the TIE-GCM is able to simulate the disturbance winds.

2. Model Description and Input Parameters

[5] As described by Fang et al. [2008], the NCAR TIE-GCM is a three-dimensional, time-dependent model which solves the full dynamical equations of the coupled thermosphere and ionosphere self-consistently [Dickinson et al., 1984; Roble et al., 1988; Richmond et al., 1992]. It is designed to calculate the coupled dynamics, chemistry, energetic, and electrodynamics of the global thermosphere-ionosphere system between about 97 and 500 km altitude. In particular, the TIE-GCM calculates the ionospheric electric fields and currents and their associated magnetic perturbations. With a specified day number of the year, F10.7 solar flux, high-latitude hemispheric power of precipitating auroral particles, and cross-polar-cap electric potential, the model calculates global electric fields and currents, ion and neutral densities, temperatures, compositions, and velocities. The solar extreme ultraviolet (EUV) radiation is specified by the EUV flux model for aeronomic calculations (EUVAC) [Richards et al., 1994; Solomon, 2006]. At the lower boundary, approximately 97 km, migrating tidal perturbations are driven by the Global Scale Wave Model (GSWM) from Hagan and Forbes [2002, 2003]. At the upper boundary, approximately 500 km, vertical O\(^+\) fluxes between the ionosphere and the plasmasphere are specified. The details of the TIE-GCM calculations of electric fields and currents and the associated magnetic perturbations are described by Doumbia et al. [2007] and Fang et al. [2008].

[6] In this study, the simulations are performed for the specific days of 11 and 21 June 1993. The geophysical indices of these days, especially the daily F\(_{10.7}\) number and 3 hourly Kp index provided by the National Geophysical Data Center (NGDC), are used to drive the TIE-GCM. The TIE-GCM uses a realistic geomagnetic field model (International Geomagnetic Reference Field) and calculates the electrodynamics in magnetic apex coordinates [Richmond, 1995]. The horizontal resolution is 5° by 5° in geographic longitude and latitude, with two grid points per scale height vertically. A higher resolution is used for calculating the electric fields and currents on a geomagnetically oriented grid, especially near the equator to resolve the EEJ. The polar cap electric potential distribution is prescribed by the Heelis et al. [1982] model. The cross-polar potential difference and the hemispheric power are estimated through the Kp index. At midlatitudes and low latitudes, the TIE-GCM solves the equations of the ionospheric wind dynamo. At auroral latitudes, the dynamo equations are modified over a transition region 15° wide, with an increasingly strong imposition of the Heelis et al. [1982] model as magnetic latitude increases toward the polar cap. (Equations (4)–(6) of Peymirat et al. [2002] detail how the electric potential is solved.) The imposed high-latitude electric potential affects the low-latitude solution in a manner qualitatively similar to the effect of direct penetration electric fields, although the TIE-GCM numerical procedure was not designed to simulate these penetration fields physically. We make use of this qualitative similarity in the present study to estimate roughly the effects of true direct penetration electric fields on the midlatitude and low-latitude magnetic perturbations.

3. Model Results

3.1. Model Simulation Context

[7] The primary goal of this study is emphasizing the disturbance dynamo effects in midlatitude and low-latitude regions on the basis of the TIE-GCM simulations. The model simulations are performed in the geophysical contexts of the quiet day 21 June 1993, for which the sum of the Kp indices is 2+, and of the storm recovery day 11 June 1993 (ΣKp = 17). Figure 1 shows variations of the Dst index (Figure 1a) and the AE index (Figure 1b) for 20–21 June (dashed lines) and 10–11 June (solid lines). On 21 June, the Dst index varies very slowly with an amplitude lower than 14 nT. The amplitude of the AE index is relatively weak as well (less than 100 nT). On 10–11 June, the Dst index (solid line) exhibits the different phases of a magnetic storm that started with an SC (sudden commencement) around 1600 UT on June 10. The SC is followed by the main phase of the storm, which started around 2000 UT and ended around 0400 UT on 11 June. The recovery phase of the storm started after 0400 UT. During the main phase of the storm, the AE index (Figure 1, bottom) is strongly enhanced, attaining a peak value higher than 1600 nT around 2300 UT on 10 June. During the recovery period, although having strongly decreased, the values of the AE index average around 200 nT, with peak values of about 300 nT at 1200 UT and 500 nT at 1800 UT on 11 June. The strong enhancement of the AE index...
indicates that the auroral activity was intensified during the main phase of the storm. Although it strongly decreases after the main phase of the storm, during the recovery the auroral activity is still important.

This study focuses on the disturbance dynamo effect by examining the diurnal variations of the simulated horizontal northward $H$ and eastward $D$ components of the geomagnetic field. The TIE-GCM model was run for the storm recovery day 11 June and the quiet reference day 21 June described above. The model includes the effects of disturbance dynamo and direct penetration of the imposed high latitude electric fields to low latitude. The diurnal variations of $H$ and $D$ simulated by TIE-GCM include these two effects, and these runs are referred to as case 2. To isolate the effect of the disturbance dynamo a second set of $H$ and $D$ calculations was performed without penetrating electric fields, which we refer to as case 1. This was done by setting the imposed high-latitude electric potential to a very small value but still using the neutral winds and conductivities from the case 2 runs when solving for the low-latitude and midlatitude electric fields and currents.

In the simulation, the strongest disturbance winds occur at high magnetic latitudes, where forcing by ion convection and Joule heating is largest. The disturbance winds also extend to midlatitudes and low latitudes, as shown in Figure 2 at 130 km altitude, between ±60° latitude, near the end of the main phase of the storm (11 June, 0 UT) and many hours after the storm main phase (11 June, 12 UT). The plots show the TIE-GCM disturbance winds, which are the difference between TIE-GCM winds on 11 June and the reference quiet day 21 June (a) for 0 UT and (b) for 12 UT.

Figure 2. TIE-GCM disturbance winds at 130 km height. The disturbance winds are determined by the difference between winds on the disturbed day 11 June and the reference quiet day 21 June (a) for 0 UT and (b) for 12 UT.
conductivity, where disturbance dynamo action is important. After the main phase of the storm, the forcing of the winds subsides and the winds relax back toward their quiet day pattern due to dissipative effects. However, between 0 and 12 UT, the disturbance winds in Figure 2 do not simply diminish in amplitude, they also change greatly in pattern, as can be seen in the longitudinal change of the largest westward winds between 0 UT and 12 UT. The winds generally maintain a westward direction during the recovery phase of the storm. Interestingly, at 12 UT a strong anticyclonic disturbance wind vortex has expanded out of high latitudes toward western North America, and the westward winds around 90°E have increased in strength in the Northern Hemisphere with respect to their values at 0 UT.

[10] Emmert et al. [2002] presented an empirical model of midlatitude daytime WINDII disturbance winds, representative of average disturbance winds during magnetically active periods, but not of poststorm winds. They showed that the average disturbance winds are roughly constant in height above about 130 km. The 0 UT winds in Figure 2 exhibit some properties of the empirical model, such as the tendency to generate a westward zonal disturbance wind at midlatitudes and the tendency for the wind strength to increase with latitude, but there are also significant differences. Whereas the empirical model shows a daytime equatorward disturbance wind component comparable with the zonal component at midlatitudes, this feature is not so apparent in Figure 2. Emmert et al. [2002] noted that there is a large amount of variability from one storm to another, and so we do not expect to find good agreement in detail. Although direct measurements of disturbance winds for a particular storm are always very sparse, we can test the simulated winds indirectly by comparing the dynamo effects they produce with observed geomagnetic perturbations, as we show in the following.

[11] Figures 3a and 3b depict the TIE-GCM equivalent current function for 11 June, 1200 UT, with near-zero polar cap potential (case 1) and with the disturbed polar cap potential (case 2), respectively. The coordinates are magnetic local time (MLT) and magnetic latitude. Figure 3a shows two hemispheric vortexes, which represent storm-modified Sq vortexes. The northern vortex, which is much more developed for these northern summer conditions, expands to the Southern Hemisphere in the morning. In Figure 3b, the current function is strongly modified at high latitudes owing to the large polar cap potential, and it is enhanced in the midlatitude and low-latitude regions owing to direct penetration of the imposed polar electric field toward lower latitudes. In section 3.2, we analyze and compare the simulated diurnal variations of the $H$ and $D$ components retrieved from the two cases in order to investigate the ionospheric disturbance associated with electric field penetrations as well as with disturbance winds.

3.2. Simulating the Ionospheric Disturbance Dynamo Effects in the Midlatitude and Low-Latitude Regions

[12] The diurnal variations of the geomagnetic field are simulated at the locations of seven observatories and temporarily stations. These stations are distributed along a meridian chain in the Europe-African longitude sector. The geographic and magnetic apex coordinates of the stations are in Table 1.

[13] Figures 4a and 4b show the simulated diurnal variations of the $H$ and $D$ components, respectively, of the geomagnetic field in the Europe-African longitude sector on 21 June 1993 (the reference quiet day) and 11 June 1993 (the disturbed day). The solid lines represent the simulations in case 1, and the dashed lines represent simulations in case 2. During the reference quiet day (Figure 4a), the amplitudes of the diurnal variations of $H$ and $D$ are similar in both cases, except for the northernmost stations, which are Lerwick (60.13°N) and Chambon-La-Foret (48.03°N), and for Sikasso (11.34°N), close to the dip equator. Small differences are observed between the diurnal variations of $H$ and $D$ in the two cases at Lerwick and Chambon-La-Foret; at Sikasso the difference is observed only for the $H$ component, owing to the enhanced east-west Cowling conductivity near the magnetic equator. The difference in the $H$ component...
In the following analysis, we therefore focus on the effect in the magnetic equator without any enhancement. In fact, the stations to midlatitude which vanishes in the vicinity of the decreasing difference in the amplitude from the northernmost component variations only.

3.3. Comparison Between Model Simulations and the polar cap current flow and of zonal flow in the equatorial system consists of two asymmetric vortices originating in simultaneously at high and low latitudes; its equivalent current time of half an hour to several hours which occurs simultaneously. The amplitude of the diurnal variation of the equatorial electrojet magnetic effects like the ring current, the effects of a symmetric ring current, as derived from the Dst index, have been removed from the observations as of Zaka et al. [2009] and Le Huy and Amory-Mazaudier [2008]. The magnitude of the observations is larger than that of the simulations in the two cases. During the disturbed day (11 June) the case 2 simulations are closer to the observations at the low-latitude stations than are the case 1 simulations. At high-latitude and midlatitude stations, the observed diurnal variation of $H$ exhibits a strong negative depression in the morning, attaining a minimum around 1130 MLT at Lerwick and 1000 MLT at Chambon-La-Forêt. Then it increases in the afternoon and gets closer to the case 2 simulation. On 21 June the morning depression is also observed at those stations, but is weaker. Note that the morning depression in the observed diurnal variations of $H$ is not reproduced by the simulations. The amplitude of the observed diurnal variation of $H$ at Sikasso near the dip equator is remarkably higher than (more than double) the simulations. Dumbia et al. [2007] also remarked that the TIE-GCM underestimates the amplitude of the diurnal variation of the equatorial electrojet magnetic effects.

3.3. Comparison Between Model Simulations and Observations

Figure 5 compares the simulated diurnal variations of $H$ on 11 June (solid lines) and on 21 June 1993 (dashed lines). Since the polar cap potential was set to nearly zero, the differences between the diurnal variations on the reference quiet day and on the disturbance dynamo day correspond primarily to the effects of the disturbance thermospheric winds, although there may also be a relatively small influence from conductivity differences on the 2 days. We notice that, unlike the effects of electric field penetrations which tend to enhance the strength of the diurnal variations of $H$ at midlatitudes and low latitudes (Figures 4a and 4b), the effects of disturbance winds tend to reduce it. Figure 5 shows the amplitude of the diurnal variations of $H$ is higher on 21 June (reference quiet day) than on 11 June 1993 (disturbance day).

### Table 1. Geographic and Magnetic Apex Coordinates of the Magnetic Stations Used in the Europe-African Longitude Sector

<table>
<thead>
<tr>
<th>Code</th>
<th>Name</th>
<th>Geographic Coordinates</th>
<th>Magnetic Coordinates</th>
<th>LT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LER</td>
<td>Lerwick</td>
<td>60.13, 358.82</td>
<td>62.37, 89.19</td>
<td>+0</td>
</tr>
<tr>
<td>CLF</td>
<td>Chambon-La-Forêt</td>
<td>48.03, 2.26</td>
<td>49.84, 85.06</td>
<td>+1</td>
</tr>
<tr>
<td>TAM</td>
<td>Tamanrasset</td>
<td>22.79, 5.53</td>
<td>24.66, 80.31</td>
<td>+1</td>
</tr>
<tr>
<td>TOM</td>
<td>Tombouctou</td>
<td>16.73, 357.00</td>
<td>6.36, 71.15</td>
<td>+0</td>
</tr>
<tr>
<td>SIK</td>
<td>Sikasso</td>
<td>11.34, 354.30</td>
<td>0.37, 67.96</td>
<td>+0</td>
</tr>
<tr>
<td>TSU</td>
<td>Tsmeb</td>
<td>−19.20, 17.58</td>
<td>−18.77, 83.51</td>
<td>+2</td>
</tr>
<tr>
<td>HER</td>
<td>Hermanus</td>
<td>−34.42, 19.23</td>
<td>−33.98, 81.35</td>
<td>+2</td>
</tr>
</tbody>
</table>

Associated with the simulated electric field penetration progressively decreases from high to low latitudes and slightly increases near the dip equator after vanishing in the midlatitude stations. In contrast, during the disturbed day (Figure 4b), the differences between the diurnal variations of $H$ in the two cases are significant in all the stations, with the highest amplitudes in the northernmost stations and at the dip equator. As regards the $D$ component variations, they exhibit decreasing difference in the amplitude from the northernmost stations to midlatitude which vanishes in the vicinity of the magnetic equator without any enhancement. In fact, the Cowling conductivity drives east-west currents that have no effect in the $D$ component variations at the magnetic equator. In the following analysis, we therefore focus on the $H$ component variations only.

[14] The trend of the latitudinal variation of the simulated direct penetration disturbance effect in the $H$ component agrees with the latitudinal profile of DP2 disturbance established by Kikuchi et al. [1996] and Kobea et al. [2000]. In fact, the DP2 disturbance associated with the fluctuations in the north-south component of the interplanetary magnetic field is characterized by a quasiperiodic variation with a time of half an hour to several hours which occurs simultaneously at high and low latitudes; its equivalent current system consists of two asymmetric vortices originating in the polar cap current flow and of zonal flow in the equatorial region [Nishida et al., 1966].

[15] In Figure 5, we compare the case 1 simulations of the diurnal variations of $H$ on 11 June (solid lines) and on 21 June 1993 (dashed lines). Since the solar cap potential was set to nearly zero, the differences between the diurnal variations on the reference quiet day and on the disturbance dynamo day correspond primarily to the effects of the disturbance thermospheric winds, although there may also be a relatively small influence from conductivity differences on the 2 days. We notice that, unlike the effects of electric field penetrations which tend to enhance the strength of the diurnal variations of $H$ at midlatitudes and low latitudes (Figures 4a and 4b), the effects of disturbance winds tend to reduce it. Figure 5 shows the amplitude of the diurnal variations of $H$ is higher on 21 June (reference quiet day) than on 11 June 1993 (disturbance day).
Ionosphere (IRI). The reasons for this are not well understood, but one possible reason could be an underestimation of the solar X-ray fluxes used by the model. We did not attempt to correct this underestimation. In section 3.4, we compare the simulated and observed disturbance dynamo effects in case 1 as well as in case 2, in order to show how important are the disturbance thermospheric wind dynamo effects at midlatitudes and low latitudes.

### 3.4. Latitudinal Variations of Simulated and Observed Disturbance Dynamo Effects

The disturbance effects are estimated for the case 1 and case 2 simulations and for observations on 11 June by subtracting the corresponding diurnal variations of the \( H \) component on 21 June 1993. In Figure 7, the resulting disturbance dynamo (\( D_{dyn} \)) effects alone (case 1) and with direct penetration electric field effects (case 2) that are associated with the 11 June disturbance simulations are compared with observations from the ground-based data. The observations represent a combination of \( D_{dyn} \) and direct penetration electric field effects. The dotted lines are the zero reference level. At Lerwick, the simulated \( D_{dyn} \) and observed disturbance are positive and have the same amplitude range, apart from the fluctuations in the observed disturbance. The amplitude of the simulated \( D_{dyn} \) with direct penetration electric field is higher than the two others.

---

**Figure 4.** (a) Diurnal variations of the horizontal (left) northward (\( H \)) component and (right) eastward (\( D \)) component of the geomagnetic field simulated by the TIE-GCM on 21 June 1993 (the reference quiet day). The solid lines represent the case 1 simulations, and dashed lines represent the case 2 simulations. (b) Same as in Figure 4a, on 11 June 1993 (the day of disturbance dynamo).
At Chambon-La-Foret, while the observed disturbance becomes negative, the simulated disturbances in the two cases remain slightly positive with very weak amplitude. At low-latitude stations (Tamanraset, Tombouctou, and Sikasso) the observations and the simulated disturbance dynamo are negative with increasing amplitudes as we get close to the dip equator, where the magnitude of the observed disturbance is 3 times as large as the simulated $D_{dynamo}$ magnitude of case 1 and more than 10 times as large as the simulated $D_{dynamo}$ with direct penetration electric field of case 2. The simulated amplitude of case 2 is very weak at the dip equator. Note that the amplitudes of both case 1 and case 2 are far weaker than the observations and that the local time of the minimum occurs earlier for the simulations (0900 LT) than for the observations (1200 LT). In the southern stations (Tsmeb and Hermanus), the observed disturbance is negative and weak, while the simulated disturbance in the two cases is nearly zero so that their traces matched exactly the zero reference level at HER. The latitudinal trend of $D_{dynamo}$ is consistent with the observations, in that the daytime horizontal $D_{dynamo}$ variations are southward at the low-latitude stations and northward at high-latitude stations. The structure of the horizontal $D_{dynamo}$ variations is associated with an equivalent current system, which flows westward at low latitudes and eastward at high latitudes. Such a current system corresponds well to the structure of an “anti-Sq” current system that had been set forth by diverse workers through observations [Fambitakoye et al., 1990]. However, the TIE-GCM model seems to underestimate the magnetic effects of this current. Indeed, the simulated disturbance in
the two cases is far weaker than the observations. It is possible that the simulated disturbance winds are too weak and may not have the correct longitudinal variation to produce the observed $D_{dy}$ variations. We noted earlier that the TIE-GCM winds at northern midlatitudes around midday have greatly diminished by 12 UT. The relatively weak disturbance winds over much of the summer hemisphere help explain the relatively weak disturbance dynamo effects predicted by the TIE-GCM. Since the disturbance winds depend on the intensity and distribution of high-latitude energy inputs during the preceding storm, it is entirely possible that the assumed distribution of the energy inputs does not adequately represent the true inputs for this storm and that the simulated winds therefore underestimate the true winds in the dynamo region. Such information can be useful to improve future modeling of thermospheric storms.

4. Conclusion

[19] In the present study, we have examined the magnetic field variations associated with the ionospheric disturbance dynamo event on 11 June 1993. This event has been simulated by the TIE-GCM and compared with observations in the Europe-Africa longitude sector. The TIE-GCM simu-
lations were performed first by ignoring the penetration of the magnetospheric convection electric field to midlatitudes and low latitudes and then by including it. In addition the geophysical conditions of 21 June 1993, selected as the reference magnetically quiet day, were used to simulate the quiet time diurnal variations of the geomagnetic field.

The analysis of the simulated diurnal variations of the \( H \) and \( D \) components of the geomagnetic field showed that the TIEGCM qualitatively reproduces the features of quiet day magnetic variations associated with the midlatitude and low-latitude ionospheric current systems, although it underestimates the amplitudes. At the dip equator, our results are in accordance with the equatorial electrojet magnetic signature analyzed by Doumbia et al. [2007]. The analysis of the geomagnetic field variations during the disturbance period showed that the contributions of the regular ionospheric wind dynamo, of the disturbance dynamo, and of the magnetospheric convection electric field penetrations overlap at midlatitudes and low latitudes. On the one hand, the effects of the disturbance dynamo tends to reduce the magnetic effects of the regular ionospheric wind dynamo, while on the other hand the effects of magnetospheric convection eastward electric field penetrations tend to increase the effects of the regular ionospheric wind dynamo currents at low latitudes. The patterns of the disturbance dynamo signature and its source “anti-Sq” current system are well reproduced in the Northern Hemisphere. However, the model significantly underestimates the amplitude of disturbance dynamo effects when compared with observations. Furthermore, the \( H \) disturbance minima occur at different local times than the observations. The discrepancies suggest that the assumed high-latitude storm time energy inputs in the model do not adequately represent the true inputs for this storm.

The magnitudes of the penetration electric field and disturbance dynamo effects are strongly enhanced at the dip equator. The mechanism of this enhancement is related to
the enhanced Cowling east-west electrical conductivity associated with the equatorial electrojet along the magnetic dip equator. During magnetically quiet days, the thermospheric wind disturbance effects do not exist or are very weak, but the effects of the convection electric field can be significant according to the level of the cross polar electric potential drop. Thus, the day to day, seasonal, and solar activity changes might have nonnegligible influences on the variability of the equatorial electrojet. At the equator, the electric field penetrations should be realistically taken into account in evaluating the disturbance as well as in analyzing the magnetic signature of the equatorial electrojet.

[22] Acknowledgments. We thank T.-W. Fang for helpful comments on an earlier draft of the manuscript. A. Richmond and A. Maute were supported in part by the NASA Living With a Star program and NASA C/NOFS Guest Investigator grant NNX09AN57G. The National Center for Atmospheric Research is sponsored by the National Science Foundation.

References


Mazaudier, C., and S. V. Venkateswaran (1990), Delayed ionosonde effects of the geomagnetic storms on March 22, 1979, studied by the sixth coordinated data analysis workshop (CDAW-6), Ann. Geophys., 8, 511–518.


Peymirat, C., A. D. Richmond, B. A. Emery, and R. G. Roble (1998), A magnetosphere-thermosphere-ionosphere-electrodynamics general-

Figure 7. Comparison with observations (dash-dotted lines) of the latitudinal variations of the simulated H disturbances associated with the disturbance wind dynamo alone (Ddyn, case 1; solid lines) and of the disturbance dynamo with penetration electric field effects (case 2; dashed lines). All values represent the difference between the disturbance dynamo day (11 June 1993) and the reference quiet day (21 June 1993). The dotted line is the zero reference level.


