Model-Based Properties of the Dayside Open/Closed Boundary: Is There a UT-Dependent Variation?

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Abstract The open-closed boundary (OCB) defines a region of significant transformation in Earth’s protective magnetic shield. Principle among these changes is the transition of magnetic field lines from having two foot points, one in each hemisphere, to one foot point at Earth, the other mapping to the solar wind. Charged particles in the solar wind are able to follow these open field lines into Earth’s upper atmosphere. The OCB also defines the polar cap boundary. Being able to identify and track the OCB allows study of several components of the geomagnetic system. Among them are the electrodynamics of the geomagnetic field and the reconnection balance between the dayside and nightside of the geomagnetic field. Furthermore, the OCB can provide insights into the precipitation of energetic protons into the ionosphere. Using the Tsyganenko model of the geomagnetic field (T96), we demonstrate a diurnal fluctuation which we call the Universal Time (UT) effect of the OCB. This UT effect is independent of all other inputs. We anticipate this UT effect to have important consequences in modeling the OCB and other polar cap-associated structures, especially polar cap absorption events that adversely affect high-frequency radio wave propagation in polar regions.

1. Introduction

It is well known that the open-closed boundary (OCB) defines the region, moving poleward, where geomagnetic field lines transition from being closed to open. Closed field lines have both foot points at or near Earth’s internal magnetic field in opposing hemispheres. Open field lines have one foot point at Earth, while the other maps to the interplanetary magnetic field (IMF) and the solar wind (SW) (Kabin et al., 2004; Newell et al., 2006; Wild et al., 2004). Charged particles are able to follow these open field lines into Earth’s upper atmosphere.

The OCB defines the polar cap boundary. Being able to identify and track the OCB allows study of several of the most important dynamic process in Earth’s geomagnetic system (Wang et al., 2016). Variations in the OCB and related changes in the size of the polar cap boundary have been linked to the net rate of magnetic reconnection on both the dayside and nightside (Chisham et al., 2004; Kabin et al., 2004; Mende et al., 2016; Wild et al., 2004). The OCB is critical to other topics in space physics including planetary magnetospheres and magnetosphere-ionosphere (M-I) coupling (Dixon et al., 2015). The OCB could also provide important insights into the equatorward limits of precipitation of energetic particles into the D-region of the ionosphere, causing polar cap absorption (PCA) events (Smart et al., 2000).

The OCB is often estimated using in situ measurements made by spacecraft transiting polar regions or by ground-based optical imagers to develop proxies for mapping the OCB (Chisham et al., 2004; Dixon et al., 2015). In addition, physics-based computational models can be used to estimate the location of the OCB (Newell et al., 2009; Rae et al., 2010; Wang et al., 2016; Wild et al., 2004). A difficulty with this approach is twofold. First, spacecraft observations are limited by their single-point sampling at the OCB. Second, ground-based imagers typically have a limited field of view. A significant barrier to a global determination of the OCB lies in the necessity to combine diverse data sets and a lack of true global coverage of observational data (Chisham et al., 2004; Rae et al., 2010).

A specific region of the dayside OCB is called the cusp, polar cusp, or separatrix. The cusp is located near the noon meridian plane (Tsyganenko & Russell, 1999) and is an area where geomagnetic field lines provide direct connection between the ionosphere and the SW via open magnetic field lines (Hunsucker & Hargreaves, 2003). An important study regarding variability of the cusp was performed by Russell (2000), showing that the geomagnetic latitude of the cusp depends on several factors including dynamic pressure...
of the SW, IMF orientation, and dipole tilt angle. Coxon et al. (2016) put the cusp at 75°, Hunsucker and Hargreaves (2003) at about 78°, and Russell (2000) at 77° geomagnetic latitude.

The location of the OCB as a reference latitude is utilized by a wide range of scientists and space weather forecasters and indirectly by amateur (Ham) radio operators. This OCB usage is to regard its latitude as an approximation of the equatorward edge of a polar region that is being impacted by energetic particles, causing PCA events. This edge is known to move equatorward as the intensity of the PCA event increases. However, this boundary at local noon, for example, would be expected to have the same geomagnetic latitude to all observers regardless of their longitude.

A Universal Time (UT) dependence has been postulated in previous works. For example, Sojka et al. (1981) identified a UT variation in high-latitude ionospheric convection arising from the superposition of an M-I convection electric field with a terrestrial corotation electric field, while Coxon et al. (2016) quantified a UT type of dependence in the location of the dayside field-aligned currents, showing that over many years and seasons, the integrated strength of the dayside currents depend upon the solar zenith angle of the ionosphere where the current closure ionospheric conductivities are located. These conductivities are dependent on solar XUV radiation and hence are modulated by changing solar zenith angle. They referred to this phenomenon as a diurnal effect.

One useful model that has been available for many years, though not specifically used as an OCB predictor, is the Tsyganenko (1995, 2002, 2016) (T96) model of the geomagnetic field. Since the T96 model has a good track record of reasonably predicting the geomagnetic field (as examples, Mende et al., 2016; Wild et al., 2004), our initial goal was to use the T96 model to study trajectories of protons with energies of 1–100 MeV through the geomagnetic field, attempting to develop a better understanding of the proton energy cutoff latitude and how the cutoff latitude, solar energetic proton events, and PCA events were related (important works in this field include Taylor, 1967; Sauer, 1963; Sauer & Wilkinson, 2008; Smart et al., 1969; Smart et al., 2000; Smart & Shea, 2001). However, model runs of proton trajectories require substantial computational resources, especially for low-energy protons (~1 MeV) that experience a great deal of geomagnetic bending and require a significant number of steps to determine if the trajectory is allowed of or forbidden (e.g., Smart et al., 2000). We hypothesized that the OCB could serve as a proxy for the energy cutoff latitude of low-energy protons.

Strictly defining open versus closed field lines on the nightside of Earth can be arbitrary (e.g., Kabin et al., 2004). This is due, in part, to the great distances to which geomagnetic field lines may be stretched in the magnetotail. Field lines that may eventually map to the SW (open) do so within time and distance scales that greatly exceed what is happening in the near-Earth geomagnetic environment. Wang et al. (2016) discuss the trade-off between reducing computational time versus an appropriate amount of data. Hence, for this study, we focus strictly on the dayside of the Northern Hemisphere, defined in this work as 0600–1800 local solar time, centered at about noon local solar time (LT). To negate any seasonal variation due to the tilt of Earth’s rotational axis toward or away from the Sun, we limited our investigation to the vernal equinox which in 2010 occurs on Day 79.

We compared our results with the Ovation Prime Real-Time (OPRT) auroral precipitation model (OVATION Prime Real-Time, 2018) described in Newell et al. (2009). OPRT and the resulting plots of auroral energy flux and total hemispheric power provide a means to compare the OCB determined by T96 with that of an empirical model of auroral electron precipitation, a frequently used proxy for determining the OCB (Coxon et al., 2016; Newell et al., 2009; Wild et al., 2004). We also compared our results with those of Rae et al. (2010), including an interval (5 June 1998) where the OCB could be determined using a combination of instruments during a sharp northward to southward IMF turning.

We evaluated the OCB as a function of several different parameters. In section 2, we examine the OCB at a specific UT as a function of LT. In section 3, we examine the OCB at a specific LT as a function of UT. In section 4, we compare our UT-dependent OCB derived from the T96 model with OPRT and with results from Rae et al. (2010). In section 5, we discuss a Space Weather (SWx) impact of the UT-dependent OCB, and in section 6, we offer a discussion about the apparent UT dependence associated with the OCB and our conclusions.
An important aspect of our intended research depends on geomagnetic storm conditions. The T96 user’s guide (Tsyganenko, 2016) states that T96 uses a linear dependence of the amplitudes of the field sources on the SW pressure, Dst, and IMF-related parameters. Therefore, best results are expected near the most probable value of the input parameters. This corresponds to the region within the specific parameter space with the highest density of spacecraft measurements. Hence, caution should be exercised in modeling situations with extremely high or low values for these parameters. Thus, extrapolating T96 too far beyond the range of reliable approximation may lead to unrealistic results. Table 1 shows the input values we used for quiet, moderate, and severe geomagnetic storm conditions. We note that the values for the Dst index and for \( B_z \) slightly exceed the envelope of T96 capabilities but do not fall in the range of “extreme” values as indicated by Tsyganenko (2016).

To determine the OCB, we first plotted field lines starting at 50° geographic latitude, so we were certain the initial point would yield a closed field line. We then moved poleward in 1° increments until we reached an open field line. We defined a closed field line as one which had both foot points located at Earth’s surface; open field lines had one foot point at Earth, the other mapping into the SW. We accomplished this by first checking the radial distance (\( R \)) of the current trace point from Earth. If the final trace point had a value of \( R = 1 \), we assumed the second foot point was also at Earth. We also used a parameter from one of the subroutines that traces the boundary between the geomagnetic field and the SW, the magnetopause. If the field line pierced the magnetopause, we assumed it was an open field line. For the study and figures associated with section 2, we studied the OCB at noon LT at 0500 UT.

Figure 1 shows one closed and two open field lines in each of three geomagnetic storm conditions at noon LT. We see in Figure 1a that the closed field line (72.0°) extends to about \( L = 12 \), where \( L \) is a variation of the well-known McIlwain (1961) parameter introduced by Plichowski et al. (2010) as “… the maximum distance from the centre of the Earth, which a point along a magnetic field line can attain ….” We also see that the first open field line (73.0°) maps to the SW. Hence, from Figure 1a, we deduce that along that particular meridian at noon LT (105.0° E), the OCB exists between 72.0° and 73.0° geomagnetic latitude for the given conditions, where geomagnetic latitude is defined by T96, based on coordinate system transformations from spherical geographic into spherical geomagnetic coordinates. Figures 1b and 1c show the OCB under moderate and severe conditions, respectively. We see that as storm conditions increase, the OCB moves equatorward and that the \( L \) value of the last closed field line decreases along both axes, as expected. For moderate conditions, the OCB lies between 66.0° and 67.0° and, for severe conditions, between 60.0° and 61.0° geomagnetic latitude.

Figure 2 is an example of dayside OCB locations at 0500 UT once all necessary geographic longitude planes at 15° intervals have been evaluated. Figure 2 shows the predicted location of the Northern Hemisphere OCB during the vernal equinox under quiet conditions at 0500 UT (solid line). We note that at noon LT, the OCB is at roughly 72.5° geomagnetic latitude. During the 0600–1800 LT regime, the OCB ranges from a minimum of 72.0° (1000 LT) to a maximum of about 78.0° (0600 LT) geomagnetic latitude. These geomagnetic parameter values are within those stated previously in this section. The impact of storm conditions is to move the OCB equatorward due to factors that apparently are largest around noon LT. Between quiet and severe conditions, the equatorward shift is about 12° at noon LT and 3.0° to 4.0° at 0600 and 1800 LT.
3. UT Dependence of the OCB

An important feature of the T96 model is the self-defined UT control based on the International Geomagnetic Reference Field. In a 24-hr period, as the geographic Earth rotates in the Sun-Earth geometry, the Earth’s magnetic field will have different orientations relative to the Sun and to the SW. Several coordinate systems exist aimed at describing this geometry. Two such systems are the Geocentric Solar-Wind and Geocentric Solar-Magnetospheric coordinate systems. Both are used by the T96 model.

How does this periodic behavior of the geomagnetic field affect the OCB? In section 2, we discussed how the T96 model was used to locate the OCB. Here we discuss what the T96 model showed us regarding the UT dependence of the geomagnetic field and the OCB. As previously discussed, it is less ambiguous to determine open versus closed geomagnetic field lines on Earth’s dayside. Hence, we looked at three LTs, all within the

![Figure 1](image1.png)

**Figure 1.** Noon meridian cross section in GSM coordinates of the OCB during quiet (a), moderate (b), and severe (c) geomagnetic conditions. A solid line in the above panels represents a closed magnetic field line; dashed and dotted lines represent open field lines. In all three panels, the horizontal axis represents the x plane, and the vertical axis represents the z plane. The sun is to the right.

![Figure 2](image2.png)

**Figure 2.** (a) shows the dayside geomagnetic latitude of the OCB for three levels of geomagnetic activity at 0500 UT from 06.00 - 18.00 Local Solar Time. (b) shows the same boundaries in a polar projection also at 0500 UT. In both panels, the solid line shows quiet, the dashed line moderate, and the dotted line severe geomagnetic conditions.
dayside, and plotted the OCB as a function of UT. To plot the OCB over a 24-hr period, we did the same procedure as described in section 2 along lines of geographic longitude at 15° intervals, beginning with the Prime Meridian. This allowed us to plot the OCB in terms of UT as well as geographic LT. Figure 3 shows these results. Several important features are apparent.

Each panel of Figure 3 has UT as the x axis and geomagnetic latitude as the y axis. Each panel of Figure 3 shows the OCB under quiet, moderate, and severe geomagnetic storm conditions. We see immediately in all three panels of Figure 3 a periodic nature to the OCB. This is most evident in Figure 3b at noon local solar time, though the cyclic behavior is manifest in all three panels. In all cases, the OCB shifts equatorward as geomagnetic storm conditions intensify, as expected.

In Figure 3b we see that under quiet conditions the OCB min/max difference is about 10°, for moderate conditions about 12°, and for severe conditions about 13° geomagnetic latitude. Furthermore, when we compare the OCB maximum that occurs at about 1500 UT in Figure 3b, we see that the OCB maximum due to geomagnetic condition changes by about 5° going from quiet to moderate and about 8° going from moderate to severe.

We see that in nearly all cases, the UT effect has a significant impact on OCB topology. Though the cyclic behavior at 0800 and 1600 LT is not as well defined as that at noon LT, the cyclic nature is readily observable. Also, it is noted that the peak in each plot has a definite shift toward a later UT as activity level increases.

In Figure 3b (Noon LT), an additional dashed line is drawn at 78° geomagnetic latitude. This provides a reference for a commonly adopted location of the dayside noon cusp-OCB. In the introduction, we discussed that this OCB location ranged from 75° to 78° geomagnetic latitude (Coxon et al., 2016; Hunsucker & Hargreaves, 2003; Russell, 2000). These values all lie within the UT range of the quiet activity noon OCB.

4. OCB and Dayside Auroral Oval

One approach commonly used for estimating the OCB is to use data gathered via ground-based measurements and/or via spacecraft as they pass through Earth’s polar regions, using the data to estimate auroral electron precipitation from which an estimate of the OCB can be made. To test the OCB determination of the T96 model, we compared it with two separate studies: (1) the OPRT model of auroral precipitation (OVATION Prime Real-Time, 2018) as described in Newell et al. (2009) and (2) The Space Weather Modelling Framework (SWMF) and associated observational data as reported in Rae et al. (2010).

4.1. OPRT

Figure 2 showed what a typical plot of the OCB taken at a single UT might look like. Since we wanted to compare T96 OCB estimates with OPRT estimates, we were careful to use inputs that matched those used to calculate OPRT images. We first looked at quiet conditions during the vernal equinox. Once we better understood the UT effect on the OCB, it made sense to plot a full 24-hr UT estimate of the OCB. Several of these are shown in Figure 4 (0500, 1100, 1700, and 2300 UT).

There are several key features apparent in Figure 4. We notice that each hour UT has an independent configuration or shape of the OCB. At noon LT for each hour UT, we notice a range of about 10° geomagnetic latitude. Under quiet conditions it appears that the OCB has a maximum equatorward extent of about 70.0° geomagnetic latitude. Furthermore, as storm conditions increase, we see an equatorward expansion of the OCB, as expected.

Figure 5 shows the minimum/maximum envelope for quiet, moderate, and severe conditions. The minimum represents the lowest geomagnetic latitude reached by the predicted OCB; the maximum value is the highest latitude. The min/max values are determined for each UT hour for the dayside sector only. Under quiet conditions, the min/max values are 72° and 83°, for moderate conditions 65° and 81°, and for severe conditions 57° and 80° geomagnetic latitude.

Figure 6 is taken directly from the OPRT data set (OVATION Prime Real-Time, 2018), based on Newell et al. (2009). It shows the auroral electron energy flux forecast based on the same inputs we used to generate Figures 2 and 4. We discussed in section 1 that the cusp is generally regarded as being at geomagnetic latitude of 75°-78°. Also, the OCB can be approximated as a circle (Coxon et al., 2016). This approximation is represented by the red arc in Figure 6.
The auroral electron energy flux is based on observed conditions and does not include an implicit UT dependence. Hence, for equivalent geophysical conditions, all OPRT plots should look the same, regardless of UT in this coordinate system. As discussed in section 3, the OCB is dynamic due to UT effect, showing a large geomagnetic latitude variance. Therefore, a more realistic comparison with the OPRT maps would be the min/max envelope as shown in Figure 5. In Figure 6, we superimposed the min/max envelope from Figure 5. Clearly the 75–78° circular approximation of the cusp lies within the UT range of the OCB derived from the T96. These UT-OCBs tend to lie at the poleward edge of the dayside oval and extend by as much as 10° latitude into the polar region. Given the lack of a direct UT component in the OPRT, the comparison is at best qualitative. However, the degree of consistency between OPRT and T96 is encouraging.

4.2. The SWMF

The SWMF is a suite of computational models used for modeling physical processes from the Sun to the Earth and consists of several models including BATS-R-US, ionospheric electrodynamics, and the Rice

Figure 3. Universal time dependence of the OCB at three levels of geomagnetic activity at 0800 (a), 1200 (b), and 1600 (c) LT. In (b), the 78° magnetic latitude approximation of the OCB at noon LT (cusp region) is shown as a heavy dashed line.

Figure 4. Dayside (Local Solar Time) polar projection for four specific UT hours under quiet (a), moderate (b), and severe (c) conditions.
Convection Model. Rae et al. (2010) tested two configurations of SWMF against a large observational data set during a sharp northward-to-southward IMF turning observed on 5 June 1998. Their Figures 2 and 3 are especially useful since they show the modeled OCB based on the two configurations of SWMF along with the observed OCB from a collection of data from several sources (see Rae et al., 2010).

Since the input data used in Rae et al. (2010) was correctly adjusted to account for the lag time between observation by the WIND instrument and interaction with the geomagnetic field (about an hour), we determined the following T96-required conditions existed at 1247 UT on 5 June 1998, prior to the $B_z$ reversal:

$$B_y \sim -4.8 \text{ nT}, \ B_z \sim 3.45 \text{ nT}, \ D_{st} \sim 3.5 \text{ nT}, \ P_{SW} \sim 5.65 \text{ nPa}.$$  

Figure 7a shows the T96 dayside OCB results superimposed over Figure 3a from Rae et al. (2010). In Figure 7a, the solid red line represents the T96 dayside OCB at 1347 UT (data suitably lagged) based on the above conditions, while the dashed orange line and dashed/dotted black line show the modeled OCB and the observed OCB from Rae et al. (2010) respectively. Throughout the dayside sector, the T96 projection of the OCB is generally within about 2–3° of their results.

We then determined that the following conditions existed at 1407 UT, after the $B_z$ reversal:

$$B_y \sim -8.3 \text{ nT}, \ B_z \sim -6.4 \text{ nT}, \ D_{st} \sim 2.0 \text{ nT}, \ P_{SW} \sim 2.0 \text{ nPa}.$$  

Figure 7b shows the T96 dayside OCB results at 1507 UT superimposed over Figure 3d from Rae et al. (2010). In Figure 7b, the T96 projection of the OCB is generally within about 3–5° of their results. In the 1200–1400 LT sector, the T96 OCB is within 2–3° and, in the 0600–0800 sector, within 1–2° of their projections. Furthermore, T96 appropriately captured the essence of the equatorward expansion of the OCB during the $B_z$ reversal. Hence, we conclude that T96 provides a reasonable prediction of the OCB.

5. OCB in Geographical Coordinates

As previously discussed, the location of the OCB is utilized by a wide range of scientists and space weather forecasters and indirectly by amateur radio operators. Typically, investigators regard the OCB latitude as an approximation of the equatorward edge of a polar region that is being impacted by energetic particles, causing PCA events. This edge is known to move equatorward as the intensity of the PCA event increases, as we have shown. The expectation, however, is that at local noon, this
boundary would have the same geomagnetic latitude to all observers regardless of their longitude. Our study suggests differently.

Figure 8 is an unconventional use of the Northern Hemisphere Mercator geographic representation. Each longitude is at a different UT such that it is at solar noon LT. The commonly used 78° magnetic latitude location of the noon OCB under quiet conditions is represented by the dotted line in Figure 8, showing the expected geographic variability in latitude. The location of our UT varying quiet time is shown as a solid line. These two quiet time OCB locations differ by as much as 10° in latitude; from 14° to 28° East longitude, the UT dependent OCB lies equatorward of the fixed OCB. The approximate location of the geomagnetic dipole is shown as a black dot. The most equatorward latitude for either OCB curve does not lie on the magnetic pole longitude (Figure 9. The fixed 78° OCB lies about 15° eastward, while the UT OCB is westward by about 15°.

In Figure 8, two additional curves are drawn to represent the UT noon OCB for moderate (dashed line) and severe (most equatorward curve) geomagnetic conditions. Note that the difference between each of the three UT dependent OCB curves is of the same order as the difference between the two quiet OCB curves. Hence, the basic UT effect being identified in this study is commensurate with the main SWx impact on this boundary. A further note is that our study is for only one seasonal condition, vernal equinox. The following section includes a further discussion on this point.

6. Discussion

M-I coupling processes lead to many standard ionospheric phenomena such as the auroral region (Hardy et al., 1985), high-latitude electric field convection (Weimer, 1995), the region of Birkeland current closures (Iijima & Potemra, 1982), and cross-polar cap potential (Reiff et al., 1981). These models are empirical models that use simple or very complex dependences on solar, SW, magnetospheric, and atmospheric conditions. These dependencies are based on indices and parameters representative of SWx dynamics. But none of these utilize an explicit UT dependence, although all the indices do have a UT reference as time series parameters.

Our study has demonstrated using a coupled representation of the solar wind, the magnetosphere, and the Earth’s magnetic field, specifically T96, that the dayside OCB has a strong UT dependence. The dayside cusp region has a strong association with the OCB since its ionospheric magnetic fields map through the dayside magnetosphere into a region of magnetic reconnection and hence the SW. The cusp, therefore, is morphologically a region that straddles closed, (equatorward) field lines and open (poleward) field lines.

Conventionally, the latitude dynamics of the cusp would be associated with SWx status, that is, during disturbed periods, the cusp would have an equatorward motion. But it would be the same magnetic latitude dependence for all geographic longitude meridians. Our study contradicts this, Figure 3b and 4 provide a
glimpse of the T96 UT dependence of the noon OCB. Figure 9 extends this noon OCB UT dependence as a function of SWx activity; the SWx indices listed in Table 1 have been three points through which a smoothly varying curve was created for each index. Across this range of SWx conditions, the UT dependence of the Noon OCB has a consistent variability of 10° to 15° in magnetic latitude.

Generating observational evidence for this suggestion is particularly challenging. A ground station is by definition located at one longitude and hence has a unique UT when it passes under the cusp region. Hence, several ground-based sites would be needed to have long-term data sets of the cusp such that statistically the SWx versus UT can be separated. Satellites perhaps have a better likelihood to have data streams capable of identifying a cusp UT dependence.

Our initial study focused on the vernal equinox. There is a strong probability that other seasons have a somewhat different UT dependence based on seasonal dependence of the geographic and hence magnetic poles in

Figure 8. Northern Hemisphere Mercator projection in geographic coordinates with the OCB shown at noon local solar time for each longitude. The solid red line represents quiet conditions; the dashed and dotted red lines show moderate and severe conditions, respectively. The dotted black line represents the OCB at 78° magnetic latitude. The black dot approximates the location of the geomagnetic north pole.

Figure 9. OCB at noon local solar time (Cusp) as function of geomagnetic conditions.
the solar/SW frame. Perhaps, an additional modeling study using advanced MHD models of the magnetosphere can provide independent quantification of this UT effect.

A rather interesting consequence of this finding would be that when the previously mentioned statistical models were generated, they were missing a key parameter, the UT effect. Figure 4 graphically shows how variable the location of a polar cap auroral boundary would be based on the location of the OCB. Historically, the locations of boundaries such as the auroral polar boundary or the equatorward precipitation boundary have never been tied to a specific SWx parameter or combination of parameters. Rather, scatter plots, with large scatter, are associated with equatorward motion of a boundary against an increasing SWx index. As stated previously, Coxon et al. (2016) quantified a UT-type dependence in the location of the day-side field-aligned currents that was not evident in Iijima and Potemra (1982). Coxon et al. (2016) also showed that over many years and seasons, the integrated strength of the dayside currents in either the Northern or Southern Hemispheres depended upon the solar zenith angle of the ionosphere where the current closure ionospheric conductivities are located. These conductivities are dependent on solar XUV radiation and hence are modulated by changing solar zenith angle. Coxon et al. (2016) referred to this phenomenon as a diurnal effect, which we have labeled a UT effect to differentiate it from a diurnal, LT, effect. The evidence presented by Coxon et al. (2016) extends over seasons for both the Northern and Southern Hemispheres. Inferences from our study implies that all M-I phenomena have a UT modulation that is of a similar magnitude as the SWx drivers. Sojka et al. (1981) identified a UT variation in high-latitude ionospheric convection arising from the superposition of an M-I convection electric field with a terrestrial corotation electric field.

7. Summary

Using the T96 model of the geomagnetic field and tracing magnetic lines originating from the Earth, we studied the location of the modeled OCB. Our findings are the following:

The geomagnetic latitude of the OCB depends on UT, even given all Space Weather drivers are held constant.

The cusp is closely associated to the noon OCB. Hence, it experiences a UT modulation of more than 10° in magnetic latitude.

Our study was for vernal equinox, there is expected to be a seasonal dependence associated with the OCB UT effect.

Our research was motivated by an interest in knowing how energetic particles such as protons can penetrate equatorward of the OCB, especially during PCA events. This paper is the lead in to such a study. Future research on this topic is to quantify the seasonal dependence of the OCB UT effect. Possible additional research will search for measurement data sets that can produce evidence of this UT effect.

Data Policy

The T96 model can be freely accessed by the public via the Community Coordinated Modeling Center (ccmc.gsfc.nasa.gov). Output data from the T96 model used for this study can be accessed via the Digital Commons of Utah State University (https://digitalcommons.usu.edu/all_datasets/80/).

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