The effect of the 135.6 nm emission originated from the ionosphere
on the TIMED/GUVI O/N2 ratio

H. Kil,1 W. K. Lee,1,2 J. Shim,3 L. J. Paxton,1 and Y. Zhang1

Received 9 July 2012; revised 1 December 2012; accepted 5 December 2012; published 15 February 2013.

[1] The column number density ratio of atomic oxygen to molecular nitrogen (O/N2 ratio) provided by the Global Ultraviolet Imager (GUVI) onboard the Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) satellite has been used as a diagnostic of the thermospheric neutral composition. However, a recent study claimed that the GUVI O/N2 ratio is not a pure thermospheric parameter in low latitudes during periods of low geomagnetic activity. This study quantifies the O/N2 ratio contamination by the ionosphere using the GUVI observations and model ionosphere acquired from 31 August to 2 September 2002. During this period, the local time of the GUVI observation was near 1500 and the average Kp index was 2°. The 135.6 nm emission originated from the ionosphere is estimated using the electron density profiles provided by the Utah State University–Global Assimilation of Ionospheric Measurements model. Our results show that the 135.6 nm emission originated from the equatorial ionization anomaly (EIA) contributes 5~10% to the total 135.6 nm intensity and O/N2 ratio. The EIA feature and longitudinal wave patterns in the GUVI 135.6 nm intensity maps are identified above an altitude of 300 km and show a good agreement with those in the F region plasma density. However, the EIA feature and longitudinal wave patterns do not appear in the GUVI 135.6 nm intensity maps below an altitude of 300 km and in the GUVI N2 Lyman-Birge-Hopfield band intensity maps in any altitude. These observations indicate that the longitudinal wave patterns in the GUVI O/N2 ratio represent the ionospheric phenomenon.


1. Introduction

[2] The column number density ratio of atomic oxygen to molecular nitrogen (O/N2 ratio) has been used as a diagnostic of the thermospheric neutral composition and its effect on the ionosphere. During geomagnetic storms, the coincidence of the plasma density and O/N2 ratio reductions in high and middle latitudes indicates the significant role of the neutral composition disturbance in the depletion of ionospheric plasma density [Crowley et al., 2006; Daniell and Strickland, 2001; Grigorenko et al., 2007; Kil et al., 2011a; Mannucci et al., 2009; Prölls, 1995; Strickland et al., 1998, 2001; Zhao et al., 2009]. The O/N2 ratio has also been used as a tool for investigating the effect of neutral composition on the creation of the semiannual anomaly (occurrence of higher plasma density during equinoxes than solstices) and the winter anomaly (occurrence of higher plasma density in the winter hemisphere than in the summer hemisphere in middle latitudes) [e.g., Fuller-Rovey, 1998; Mendillo et al., 2005]. Recently, the O/N2 ratio was recognized as a tool for probing the thermosphere-tide coupling [Engl et al., 2010; He et al., 2010; Zhang et al., 2010].

[3] The measurements of the far ultraviolet emissions by the Global Ultraviolet Imager (GUVI) onboard the Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) satellite have been the major source of the O/N2 ratio data in the past decade. TIMED/GUVI O/N2 ratio is derived from measurements of the height-integrated atomic oxygen (OI) 135.6 nm and N2 Lyman-Birge-Hopfield short (LBHS) band (141.0–152.8 nm) intensities [Strickland et al., 2004a, 2004b; Zhang et al., 2004]. In the thermosphere, the N2 LBHS band and OI 135.6 nm emissions are produced by the impacts of photoelectrons. The OI 135.6 nm emission is also produced by the recombination of O+ and subsequent de-excitation. Because height-integrated 135.6 nm emission associated with the recombination (135.6 nm emission originated from the ionosphere and hereafter I135.6) is much smaller than that associated with the impacts of photoelectrons (135.6 nm emission originated from the thermosphere and hereafter A135.6) in the dayside, the ionospheric effect on the O/N2 ratio retrieval has been ignored. However, Kil and Paxton [2011a] claimed that I135.6 originated from the equatorial ionization
anomaly (EIA) could be the primary source of the longitudinal and latitudinal variation of the O/N2 ratio in low latitudes during periods of low geomagnetic activity.[4] Kil and Paxton [2011a] suggested the contamination of the GUVI O/N2 ratio by $I_{135.6}$ based on similarities between the morphologies of the GUVI O/N2 ratio and plasma density. We extend the previous study by quantifying $I_{135.6}$ and its contribution to the O/N2 ratio. $I_{135.6}$ is calculated using the electron density profiles provided by the Utah State University-Global Assimilation of Ionospheric Measurements (USU-GAIM) model. We use the USU-GAIM model ionosphere scaled with the electron density measurements from the CHAllenging Minisatellite Payload (CHAMP) satellite. The investigation is carried out with the average data acquired during 31 August to 2 September 2002. During this period, the CHAMP and TIMED local times (LTs) were closely matched (1500 LT) and geomagnetic storms were absent.

2. Instrument and Data Description

[5] The TIMED spacecraft is in a 625km circular orbit with an orbital inclination of 74.1°. GUVI provides scan images of the Earth’s disk and limb in five colors: HI 121.6nm, OI 130.4nm, OI 135.6nm, and N2 LBH bands from 141.0 to 152.8nm (LBHS) and from 167.2 to 181.2nm (LBHL) [Paxton et al., 1999; Christensen et al., 2003]. The TIMED satellite precesses 360° in 120 days so that each LT is sampled every 60° in 120 days by combining the ascending and descending orbits. The GUVI O/N2 ratio is derived from the ratio of OI 135.6 and LBH radiances [Zhang et al., 2004].

[6] The CHAMP satellite was launched on 15 July 2000 in a near-circular orbit at an altitude of 456km. The orbital inclination was 87.25°. The CHAMP satellite was at an altitude of near 400km in 2002. Due to the precession of the orbital plane at a rate of 5.6min/day, the CHAMP observations take 131 days to cover all LTs by combining the ascending and descending orbits. The CHAMP data are available at a rate of one sample each 15s.

[7] The USU-GAIM model was developed at Utah State University as part of a United States Department of Defense Multidisciplinary University Research Initiative program [Schunk et al., 2004]. The USU-GAIM model provided to the Community Coordinated Modeling Center (CCMC) in National Aeronautics and Space Administration (NASA) assimilates total electron content data provided by the ground global positioning system network of 150–200 stations between ±60° geographic latitude. We calculate $I_{135.6}$ using the USU-GAIM model ionosphere provided by NASA/CCMC after scaling of the model ionosphere with the CHAMP electron density data.

3. Results

[8] Figure 1 presents the GUVI O/N2 ratio map produced using the data between 25 August and 3 September 2002. The map is produced using 10 day data to acquire sufficient data points on each 10° longitude bin. The sampling LT range during that period was 1400–1600. The O/N2 ratio map shows the formation of the longitudinal wave number 4 pattern which is similar to that identified in the F region plasma density [Kil and Paxton, 2011b]. The longitudinal wave number 4 pattern in the ionosphere describes the longitudinal distributions of the plasma density and vertical plasma drift in low latitudes at a fixed LT during magnetically quiet periods. This phenomenon is known to be associated with the modulation of the E region dynamic electric field by the diurnal eastward-propagating zonal wave number 3 tide [England et al., 2006; Immel et al., 2006]. The O/N2 ratio peaks appear at the typical latitudes where the EIA develops. The longitudinal wave number 4 pattern in the O/N2 ratio is produced by its longitudinal variation of 5~10%. In the following, we examine whether the 5~10% variation of the O/N2 ratio is accounted for by the variation of $I_{135.6}$.

[9] The 135.6nm intensity observed by GUVI is the sum of $I_{135.6}$ and $A_{135.6}$. Assuming that the oxygen ion density is the same as the electron density in the dayside below the TIMED altitude (625km), $I_{135.6}$ up to the TIMED altitude is given in Rayleigh (R) unit by

$$I_{135.6}(z) = 10^{-13} r(z) a(z) dz.$$  \hspace{1cm} (1)

[10] Here $a$ is the radiative recombination rate coefficient of the oxygen ion and $n_e$ is the electron number density. The unit for $a$ is cm$^3$s$^{-1}$ and the unit for density is cm$^{-3}$. The $a$ value is expressed as a function of the electron temperature ($T_e$). Some examples in literature are

$$a = 7.8 \times 10^{-14} \times (300/T_e)^{0.5} \text{[cm}^3\text{s}^{-1}] \quad [\text{Brekke, 1997}]$$  \hspace{1cm} (2)

$$a = 7.3 \times 10^{-13} \times (1160/T_e)^{0.5} \text{[cm}^3\text{s}^{-1}] \quad [\text{Meléndez-Alvira et al., 1999}]$$  \hspace{1cm} (3)

$$a = 3.7 \times 10^{-12} \times (250/T_e)^{0.7} \text{[cm}^3\text{s}^{-1}] \quad [\text{Schunk and Nagy, 2000}]$$  \hspace{1cm} (4)

$I_{135.6}$ can be directly calculated from equation 1 using the electron density profiles provided by the USU-GAIM model. Prior to the calculation of $I_{135.6}$, we used the CHAMP electron density data as a constraint to the model. Figure 2a shows the CHAMP electron density at 50° (red curve) and 100°E (black curve) longitudes as a function of magnetic latitude. The latitudinal profiles present the average density (three-point mean) during 31 August to 2 September 2002 and the vertical bars show the standard deviations. Throughout the figures in

Figure 1. The TIMED/GUVI O/N2 ratio map produced by using the data at 1400–1600 LT between 25 August and 3 September 2002.
the following, we use the average data in the longitude ranges 40°–60°E and 90°–110°E to represent the longitude regions of 50° and 100°E, respectively. The 50°E longitude corresponds with the location of a trough and the 100°E longitude corresponds with the location of a crest in the wave number 4 patterns of the F region plasma density [Kil and Paxton, 2011b]. In Figure 2a, we can see the development of the EIA peaks around ±12° magnetic latitudes at 50°E longitude and around ±18° magnetic latitudes at 100°E longitude. The EIA at 100°E longitude is stronger than that at 50°E longitude, but the plasma density at the magnetic equator is greater at 50°E longitude than at 100°E longitude. These longitudinal differences of the latitudinal electron density profiles are attributed to the longitudinal difference of the vertical plasma drift. In comparison of the electron density profile with the O/N₂ ratio map in Figure 1, the development of intense EIAs near 100°E longitude in the electron density profile is consistent with the development of pronounced O/N₂ ratio crests in that region. The EIA and O/N₂ ratio peaks are located at the same magnetic latitudes. Figure 2b presents a sample plot of the USU-GAIM model ionosphere (black curve) and the one scaled with the CHAMP electron density (red curve). The red star symbol indicates the electron density observed by CHAMP.

[11] Figures 3a and 3b present $I_{135.6}$ at 50° and 100°E longitudes obtained from the USU-GAIM model ionosphere after scaling with the CHAMP electron density data. The results obtained with the use of the recombination rate coefficients given by equations 2–4 are shown with green, black, and red curves. The integration was made up to the TIMED altitude (625km) and the recombination rate coefficient was assumed to be constant with the input electron temperature of 1800K. $I_{135.6}$ with green color is considered to be unrealistically small because the daytime $I_{135.6}$ obtained with the $\alpha$ value given by equation 2 is much smaller than the nighttime 135.6nm intensity. Figures 3c and 3d show the $A_{135.6}$ profiles at 50° and 100°E longitudes. The $A_{135.6}$ profiles with green, black, and red colors are obtained by subtractions of the $I_{135.6}$ profiles (Figures 3a and 3b) from the total 135.6 nm intensity (GUVI observation). The total 135.6 nm intensities observed by the GUVI disk scans are shown with blue dots. The standard deviations (vertical blue bars) show the day-to-day variation range of the GUVI 135.6 nm intensity.

The $A_{135.6}$ profiles with green color are not clearly visible because they are close to the total 135.6 nm intensity profiles with blue dots. In the red curves, deep troughs appear at the locations of the EIAs. Those troughs are considered to be produced by the combination of the uncertainties in the recombination rate coefficient, model ionosphere, and GUVI measurements. Uncertainties for the GUVI 135.6 nm intensity are related to the counting statistics and the 121.6 and 130.4 nm scattered light removal. The uncertainty for an individual pixel is about 10% in the dayside. For our GUVI results, the uncertainty is substantially reduced because each longitude and latitude bin has sufficient number of photon

---

**Figure 2.** (a) The latitudinal electron density profiles at the longitudes of 50° (red curve) and 100°E (black curve). The observations were made an altitude of 400km during 31 August to 2 September 2002 by CHAMP. The vertical bars show the standard deviations. (b) A sample USU-GAIM model ionosphere at 18° magnetic south at 100°E longitude (black curve). The red curve is the USU-GAIM model ionosphere scaled with the CHAMP electron density indicated by a red star symbol.

**Figure 3.** (a and b) $I_{135.6}$ obtained with the three recombination rate coefficients at 50° and 100°E longitudes. (c and d) $A_{135.6}$ at 50° and 100°E longitudes. The results obtained with the recombination rate coefficients given by equations 2–4 are shown with green, black, and red curves, respectively. The total 135.6 nm intensity observed by GUVI is shown by blue dots with standard deviations.
The amounts cause the O/N$_2$ ratio variation of 2~3% at 50° expressed by the sum of R$_{20}$~30 variation of the O/N$_2$ ratio at the two longitudes in Figure 1.

Thus longitudinal difference in 135.6nm intensity at 50°E longitude below an altitude of 300km (see Figure 4a). However, the equatorial 135.6 difference of the 135.6nm intensity is significantly reduced with that given by equation 2 or 4, is closer to the actual value. Among the solid curves, the results obtained with the use of the recombination rate coefficient given by 3 (black color) are closest to the blue dots. This result may indicate that the recombination rate coefficient given by equation 3, compared with that given by equation 2 or 4, is closer to the actual value. In the blue curves, the fractional I$_{135.6}$ varies up to 10%. Because the LBH intensity shows only a minor longitudinal and latitudinal variation, the O/N$_2$ ratio variation caused by I$_{135.6}$ is close to this amount. In the magnetic south at 50°E longitude (Figure 5b), the fractional I$_{135.6}$ profiles with blue dots are significantly different from those shown with red and black curves. The difference can be produced because the plasma density provided by the model ionosphere is greater than the actual plasma density or because the recombination rate coefficient or the plasma density in the model ionosphere is greater than their real values. The recombination rate coefficient given by equation 3 has been commonly used when plasma density is retrieved from the nighttime GUVI 135.6nm observations [e.g., Comberiate et al., 2007; DeMajistre et al., 2004]. Thus the troughs on the A$_{135.6}$ profiles with red color are seen to be related to the recombination rate coefficient given by equation (4). In the black curves in Figures 3a and 3b, the difference of I$_{135.6}$ between the magnetic equator and EIA is 20~30R at 50°E longitude and 70~100R at 100°E longitude. These amounts cause the O/N$_2$ ratio variation of 2~3% at 50° E longitude and 7~10% at 100°E longitude. The latitudinal variation of the O/N$_2$ ratio at the two longitudes in Figure 1 is consistent with the latitudinal variation of I$_{135.6}$.

[12] The GUVI limb observations provide a tool to examine the height where the longitudinal and latitudinal variation of the 135.6nm intensity occurs. In Figure 4, we compare the GUVI limb measurements of the 135.6nm intensity at (Figure 4a) the magnetic equator, (Figure 4b) 18°S magnetic latitude, and (Figure 4c) 18°N magnetic latitude. The data acquired during 31 August to 2 September 2002 at 50° and 100°E longitudes are shown with the red and black curves, respectively. Above an altitude of ~300km, the 135.6nm intensity at the EIA locations (±18° magnetic latitudes) is greater at 100°E longitude than at 50°E longitude. At the magnetic equator, the 135.6nm intensity at 50°E longitude is greater than that at 100°E longitude. These results are consistent with the longitudinal difference of the ionospheric 135.6 nm intensities shown in Figures 3a and 3b. The longitudinal difference of the 135.6nm intensity is significantly reduced below an altitude of 300km. However, the equatorial 135.6 nm intensity at 50°E longitude is consistently greater than that at 100°E longitude below an altitude of 300km (see Figure 4a). Thus longitudinal difference in $A_{135.6}$ also exists.

[13] If the longitudinal difference in $A_{135.6}$ is much smaller than that in I$_{135.6}$, we can remove the uncertainty related to the recombination rate coefficient in the derivation of $A_{135.6}$ and I$_{135.6}$ from the GUVI 135.6nm intensity data. The GUVI 135.6nm intensity is the total intensity ($I_{135.6}$) expressed by the sum of I$_{135.6}$ and $A_{135.6}$. By distinguishing two longitude regions with subscripts 1 and 2 and omitting the subscript 135.6, the relationship is written as $T_1 = I_1 + A_1$ (5) $T_2 = I_2 + A_2$. (6)

[14] The fractional difference of I$_{135.6}$ at two longitudes is written as

$$ K = \frac{I_1 - I_2}{I_2} = \frac{(T_2 - A_2) - (T_1 - A_1)}{T_2 - A_2}. $$(7)

[15] Assuming $A_1 = A_2 = A$, we obtain

$$ A = T_2 - \frac{1}{K} (T_2 - T_1). $$

[16] Here K is derived from the USU-GAIM electron density profiles scaled by the CHAMP data. Because the recombination rate coefficient is assumed to be constant in the F region, it cancels out by taking the intensity ratio. We apply this method to the observations at 50° and 100°E longitudes. Figure 5a presents A$_{135.6}$ obtained from equation 8 with blue dots. The total 135.6nm intensities (GUVI disk scans) at 50° and 100°E longitudes are shown with red and black colors, respectively. The EIA-like feature does not appear on the A$_{135.6}$ profile. Figures 5b and 5c show the fractional I$_{135.6}$ (ratio of I$_{135.6}$ to the total 135.6nm intensity) at 50° and 100°E longitudes, respectively. The blue curves with dots are the fractional I$_{135.6}$ derived from the results shown in Figure 5a. The solid red and black curves are the fractional I$_{135.6}$ obtained from the USU-GAIM model (curves shown in Figure 3). Among the solid curves, the results obtained with the use of the recombination rate coefficient given by 3 (black color) are closest to the blue dots. This result may indicate that the recombination rate coefficient given by equation 3, compared with that given by equation 2 or 4, is closer to the actual value. In the blue curves, the fractional I$_{135.6}$ varies up to 10%. Because the LBH intensity shows only a minor longitudinal and latitudinal variation, the O/N$_2$ ratio variation caused by I$_{135.6}$ is close to this amount. In the magnetic south at 50°E longitude (Figure 5b), the fractional I$_{135.6}$ profiles with blue dots are significantly different from those shown with red and black curves. The difference can be produced because the plasma density provided by the model ionosphere is greater than the actual plasma density or because A$_{135.6}$ derived from equation 8 is greater than the actual A$_{135.6}$. The EIA in the magnetic south at 50°E longitude is weaker than these amounts.
that in other regions. Presumably, our assumption (the same \( A_{135.6} \) at the two longitudes) causes greater errors in the region where the EIA is weaker. Here we emphasize that about 10% contribution of \( I_{135.6} \) to the GUVI 135.6nm intensity is not related to the uncertainty in the recombination rate coefficient.

To further demonstrate that the variation of the GUVI 135.6nm intensity in low latitudes is associated with the ionosphere, we compare the average GUVI 135.6nm intensities in the altitude intervals (Figure 6a) 400–520km and (Figure 6b) 150–300km. Those maps were produced with GUVI limb data acquired between 25 August and 3 September 2002. The LT was near 1700. The longitudinal wave number 4 pattern and the EIA-like feature are visible in the 135.6nm intensity maps obtained above an altitude of 400km. However, those features do not appear in the 135.6nm intensity obtained below 300km altitude. Those features did not appear in the GUVI LBH maps at any altitudes. No observation or model showed the anomalous behavior of the thermosphere at the locations of the EIA; the anomalous enhancement of the neutral mass density appears in about 10° higher latitudes than the EIA locations [Liu et al., 2007]. So, the enhanced 135.6nm intensity at the EIA locations and its longitudinal variation are not explained by \( A_{135.6} \).

The longitudinal wave pattern in the ionospheric plasma density shows a seasonal variation [Kil et al., 2008, 2011b, 2012; Scherliess et al., 2008]. A similar seasonal variation may appear in the GUVI 135.6nm intensity, if the ionosphere is the major source of the variation of the GUVI 135.6nm intensity. Figure 7 presents (Figure 7a) the GUVI 135.6nm intensity maps in the topside (400–520km) and (Figure 7b) the plasma density maps produced using the first Republic of China satellite (ROCSAT-1) data. The ROCSAT-1 satellite was operated at an altitude of 600km from March 1999 to June 2004. Those maps are produced using the data between 1200 and 1700 LT. The GUVI 135.6nm intensity maps in March, May, July, September, and November are produced using the data from 2002. Because GUVI data are partially available in January 2002, the 135.6nm intensity map in January is produced using the data from 2003. To acquire sufficient data points on each longitude and latitude bin, the ROCSAT-1 plasma density maps are produced using the data acquired during March 1999 to June 2004 under the conditions \( Kp \leq 3 \) and \( 130 < F_{10.7} < 200 \ [10^{-22} \text{Wm}^{-2} \text{Hz}^{-1}] \). The \( F_{10.7} \) index is the measure of the solar radio flux at a wavelength of 10.7cm. Because the longitudinal wave pattern in the ionosphere does not vary with the solar cycle during the period of 1999–2004 [Kil et al., 2012], Figure 7b can be considered a representation of the ionospheric longitudinal wave pattern. The seasonal variations of the longitudinal wave pattern in the GUVI 135.6nm intensity and plasma density are similar. The common characteristics in both observations are (1) the occurrence of the pronounced crest near 100°E longitude, (2) the development of a clear wave number 4 pattern in September, and (3) the creation of weaker crests between 150° and 300°E longitudes than in other longitudes in July. The appearance of the characteristics of the ionospheric longitudinal wave patterns in the 135.6nm intensity provides strong evidence that the ionosphere is the source of the longitudinal wave patterns in the GUVI 135.6nm intensity in low latitudes. Because the variation of the O/N\(_2\) ratio in low latitudes is primarily caused by the variation of the 135.6nm intensity, the EIA-like feature and longitudinal wave patterns in the O/N\(_2\) ratio represent the phenomena in the ionosphere.

**Figure 5.** (a) Estimation of \( A_{135.6} \) from the total 135.6nm intensity (GUVI observation). The estimation is shown with blue dots. The GUVI 135.6nm intensity data at the longitudes of 50° and 100°E longitudes are shown with red and black curves, respectively. (b and c) Fractional \( I_{135.6} \) at 50° and 100°E longitudes. The blue curves with dots are obtained from Figure 5a. The red and black curves are obtained from the results shown in Figures 3a and 3b.

**Figure 6.** The GUVI 135.6nm intensity maps in the altitude ranges of (a) 400–520km and (b) 150–300km.
We have investigated the origin of the longitudinal wave patterns in the TIMED/GUVI O/N₂ ratio in low latitudes by analyzing the TIMED/GUVI 135.6nm intensity measurements and the USU-GAIM model ionosphere data acquired during 31 August to 2 September 2002. During this period, the GUVI LT was near 1500 and the average Kp index was 2°. Our results obtained from model calculations show that the 135.6nm emission originated from the EIA contributes up to 10% to the total 135.6nm intensity. The EIA-like features and longitudinal wave patterns appear in the GUVI 135.6nm intensity maps produced using the data acquired in the topside (400–520km). The seasonal–longitudinal variation of the 135.6nm intensity in the topside is similar to the seasonal–longitudinal variation of the plasma density in the F region. However, the EIA-like feature and longitudinal wave patterns do not appear in the 135.6nm intensity maps produced using the data acquired below an altitude of 300km. These observations demonstrate that the variation of the GUVI 135.6nm intensity in the afternoon in low latitudes is associated with the 135.6nm emission originated from the ionosphere. Because the EIA-like feature and longitudinal wave patterns do not appear in the LBH band intensity maps at any altitudes, the 135.6nm emission originated from the EIA is the primary source of the longitudinal wave pattern in the GUVI O/N₂ ratio.

The O/N₂ ratio contamination identified from this study is limited to the periods during which strong EIA develops under low geomagnetic activity conditions. The O/N₂ ratio contamination is not considered to be an issue at any LT in middle latitudes where the plasma density is low. Because the EIA strength varies with LT and solar cycle, the severity of the O/N₂ ratio contamination will also vary with those factors. The dayglow brightness of 135.6nm and LBHS decreases with an increase in the solar zenith angle. Therefore, the contamination of the dayside GUVI 135.6nm intensity and O/N₂ ratio by the ionosphere will increase toward the evening terminator. The dependence of the O/N₂ ratio contamination on those factors requires further investigation in the future. The O/N₂ ratio contamination during geomagnetic storms has not yet been investigated. As model simulations have shown [e.g., Crowley et al., 2006], thermospheric neutral composition change is considered to be the primary source of the GUVI O/N₂ ratio disturbances during storm periods. However, severe ionospheric disturbances also occur during storm periods and their effect, especially the effect of severe plasma density enhancements on the GUVI O/N₂ ratio enhancements in middle latitudes, is worth investigating.

Acknowledgments. H. Kil acknowledges support from NASA NNX12AD17G and NSF National Space Weather Program (AGS-1024886) grants. W. K. Lee acknowledges support from University of Science and Technology Post-Doc Research Program in Korea. Simulation results have been provided by the Community Coordinated Modeling Center (CCMC) at Goddard Space Flight Center through their public Runs on Request system.


