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Variations of the Topside Ionospheric and Plasmaspheric Electron Content Derived from the COSMIC podTEC Observations and Comparison with the IZMIRAN_Plas Model Results

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ABSTRACT

The variations of the topside ionospheric and plasmaspheric electron content (PEC) are studied using data derived from the podTEC observation of the COSMIC low Earth orbit (LEO) satellite to the GPS satellite signals. We first give a brief introduce to the method we used to convert the slant podTEC to the vertical PEC which corresponds to the vertical integrated electron content from an altitude of about 800km of the LEO satellite to the altitude of about 20200km of the GPS satellites. Then we used the converted PEC data of the whole year 2008 to study the variations of PEC with the geomagnetic latitude (MLAT), magnetic local time (MLT) and with four different seasons (March equinoctial, June Solsticial, September Equinoctial and December Solsticial). A comparison study is also made between the observational results and those provided by the IZMIRAN_Plas model. Additionally, we also study the longitudinal difference of the PEC's seasonal variation using data extracted from two different longitudes. Our study showed that: (1) The distribution of the topside and plasmaspheric electron content PEC is mainly confined to a region of $\pm 45^0$ of the magnetic equator of the Earth; (2) PEC shows a well-defined diurnal variation pattern with higher values during daytime hours than during nighttime hours. PEC reaches its peak value at the hour around 12-16MLT, whereas it reaches its minimum value at around 4-5 MLT. (3) PEC has a lowest value in the June Solsticial season compared with other seasons. (4) PEC shows an evident longitudinal variation and it has different seasonal variations for different longitudes. (5) The IZMIRAN_Plas model results generally underestimate the observed PEC values, particularly in the low-latitude region during nighttime hours.

Key words: Ionosphere, Plasmasphere, TEC, Diurnal and Seasonal Variations, GPS

1. Introduction

Radio signals transmitted from GPS satellite going through the ionization zone above the Earth will be refracted by the ionized components in the ionosphere and the plasmasphere, which would produce additional transfer delay relative to the situation in vacuum and generate extra errors in satellite navigation and positioning, timing, remote sensing and telemetering. These errors have strong relation with the total electron content (TEC) along the signal's travelling path. Therefore TEC is one of the most important parameters required by many users for different modern usage purposes such as ionospheric range error correction required by geodetic community. The topside ionospheric and plasmaspheric electron content makes a large contribution to TEC. Study on the variations of the topside ionospheric and plasmaspheric electron content is a significant part of the space weather issues. In this study, we will present our recent study on the diurnal and seasonal variations of the topside ionospheric and plasmaspheric electron content (PEC) between the heights of 800-20200km above the Earth using data derived from the podTEC measurements of the COSMIC low Earth orbit satellites to the GPS signals. A comparison study of the observed PEC with the IZMIRAN_Plas model [1] results will be also presented.

2. **Source Data Used and Preprocessing Method**

The source data we used for our present study is the COSMIC 'podTEC' data set archived in the COSMIC Data Analysis and Archive Center (CDAAC, http://cosmic-io.cosmic.ucar.edu/cdaac/index.html). We used the podTEC data of the whole year of 2008. For studying the seasonal variations of PEC, the data is divided into four groups according to the following seasons: March Equinoctial (Mar-Apr), June Solsticial (May-Aug); September Equinoctial (Sep-Oct), December Solsticial (Jan-Feb & Nov-Dec).

The method we used to derive PEC from podTEC involves a slant-to-vertical TEC conversion technique using a mapping function $f(\varepsilon)$:

$$PEC = podTEC \times f(\varepsilon) \qquad (1)$$

where *podTEC* is the upward looking TEC measurement of the COSMIC low Earth orbit (LEO) satellite's precise orbit determination antenna to GPS signals. The mapping function $f(\varepsilon)$ is expressed as[2]

$$f(\varepsilon) = \frac{\sin\varepsilon + \sqrt{(R_{ppt}/R_{orb})^2 - (\cos\varepsilon)^2}}{1 + R_{ppt}/R_{orb}} \qquad (2)$$

$$R_{ppt} = R_e + H_{ppt} \qquad (3)$$

$$R_{orb} = R_e + H_{orb} \qquad (4)$$

Where ε is the elevation angle of the LEO-GPS ray path, *Re* is the Earth radius, *Hppt* is the altitude of the pierce point of the LEO-GPS ray path in the plasmasphere and *Horb* is the altitude of the COSMIC LEO satellites' orbit. For the present study, *Hppt* is taken as 3000km [2].

3. **Results**

Figure 1 shows the latitudinal, diurnal and seasonal variations of PEC of the year 2008. From the left to the right panels are cases for the four seasons: M-Equin, J-Sols, S-Equin and D-Sols. The upper panels are the results derived from the COSMIC podTEC measurements and the lower panels are the results provided by the IZMIRAN_Plas model. From figure 1, it can be seen clearly that PEC is mainly confined to a region of $\pm 45^0$ of the magnetic equator of the Earth; PEC shows a well-defined diurnal variation pattern with higher values during daytime hours than during nighttime hours: PEC reaches its peak value at the hour around 12-16MLT, whereas it reaches its minimum value at around 4-5 MLT. It is also seen that PEC has a lowest value in the June Solsticial season compared with other seasons. From the plots in the lower panels, we can see that although the seasonal variation tendency of the observed PEC is captured by the IZMIRAN_Plas model, the model results generally underestimate the observed PEC values, particularly in the low-latitude region during nighttime hours. Moreover, the IZMIRAN_Plas model results tend to show a double-peak feature in the low-latitude region, which is not observed in the observational PEC results.

Figure 2 shows the observed variations of PEC in four seasons at 120^0E and 300^0E for the year 2008. It can be seen that PEC shows an evident longitudinal dependence and it has different seasonal variations for different longitudes: very weak seasonal variations (with only a slight semi-annual variation) are observed for PEC at the longitude 120^0E; in contrast, PEC at the longitude 300^0E shows a strong annual variation with lowest value in the J-solstice and highest value in the D-solstice months;

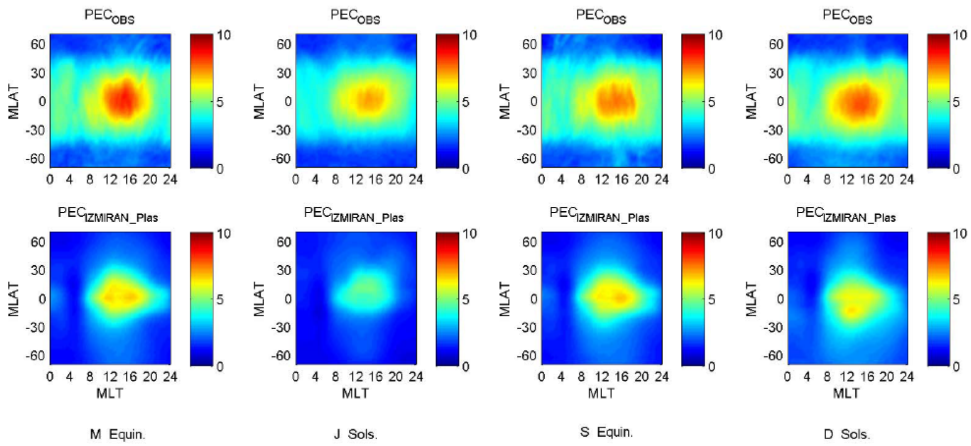

Fig. 1 Latitudinal, diurnal as well as seasonal variations of PEC for the year 2008. (Upper panels are the observational results and lower panels the IZMIRAN_Plas model results. Panels from left to right are for the four seasons: M-Equin, J-Sols, S-Equin and D-Sols.)

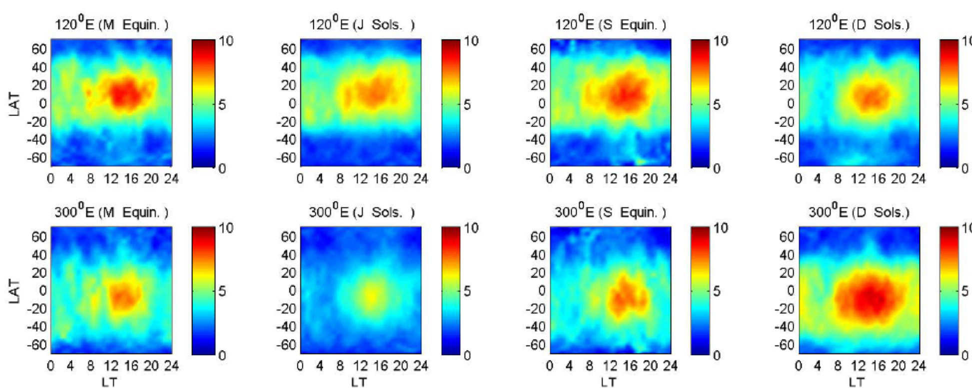

Fig. 2 Longitudinal difference of the observed PEC's seasonal variation for the year 2008.

4. References

[1] Gulyaeva, T. and D. Bilitza, (2012). Towards ISO Standard Earth Ionosphere and Plasmasphere Model, in New Developments in the Standard Model, pp. 1-48. Editor: Ryan J. Larsen., ISBN: 978-1-61209-989-7, ©2012 Nova Science Publishers, Inc.

[2] Yue X, Schreiner W S, Hunt D C, et al. (2011). Quantitative evaluation of the low Earth orbit satellite based slant total electron content determination, Space Weather, 2011, 9:S09001. doi:10.1029/2011SW000687.

5. Acknowledgements

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