Comparison of global TEC between IRI TEC and GPS TEC in the spring of 2006

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Abstract

Comparison of the global Total Electron Content (TEC) derived from dual-frequency Global Positioning System (GPS) data and International Reference Ionosphere (IRI) used tomographic models, it has very important significance for IRI upgrading [1]. We investigate the trend of global TEC between IRI TEC and GPS TEC in the spring of 2006. IRI TEC is derived from the IRI-2012 model and GPS TEC is obtained from the International GNSS service (IGS) [1, 2]. By comparing the results, IRI TEC agrees with GPS TEC very well at high latitudes. They are generally in agreement even at low latitudes for the period from evening to morning. However, differences are found from 11:00-17:00 LT at low latitudes. It can be seen that the north-south asymmetry has remarkable effect on both IRI TEC and GPS TEC, especially in the equatorial ionization anomaly (EIA). The strength of EIA crest is obviously higher in north than in south about IRI TEC, it reaches ~11 TECU around 15° E longitude at 13:00 LT. Meanwhile, EIA crest in daytime is generally exaggerated and the noon-bite out is deep in the IRI TEC than GPS TEC, the difference of noon-bite is about 12 TECU around 105° E longitude at 13:00 LT.

1. Introduction

The ionosphere is a dispersive medium that causes a phase rotation or time delay in transionospheric radio waves used for radio astronomy and satellite navigation. The time delay of a radio wave propagating through the ionosphere is proportional to the Total Electron Content (TEC) along its ray path. Measurement of TEC is useful for ionospheric correction in a transionospheric radio system [3, 4, 5, 6].

Since the Global Positioning System (GPS) was opened up for public usage, the ionospheric TEC has been measured with dual frequency GPS receivers economically and effectively. GPS TEC has become the most used parameter in studying ionospheric properties, constructing ionospheric models and making ionospheric corrections [7, 8].

Meanwhile, ionospheric models has been often used to correct the measurements or time delay for ionospheric radio systems. The international reference ionosphere (IRI) is the internationally recognized and recommended standard for a climatological specification of ionospheric parameters [9]. It is a data-based empirical model, and was developed making use of all available and reliable data sources for the ionospheric plasma. IRI model is continually upgraded as new data and new modeling approaches become available. The latest version is IRI-2016 [10].

This study aims to compare global TEC between IRI TEC and GPS TEC in the spring of 2006. IRI TEC is derived from the IRI-2012 model and GPS TEC is obtained from the International GNSS service (IGS). The extraction method of IRI TEC and GPS TEC are presented in Section 2. Section 3 displays the results. It discusses the characteristic of them, especially the north-south asymmetry of TEC at the anomaly crests. Finally the conclusions are given in Section 4.

2. Acquisition of TEC

The data were from five geomagnetically quiet days around equinoxes during a low solar activity phase in the year 2006. The days selected were from 5 March to 9 March.

2.1 IRI TEC calculation

The International Reference Ionosphere (IRI) is an international project sponsored by the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI). These organizations formed a Working Group in the late sixties to produce an empirical standard model of the ionosphere, based on all available data sources. Several steadily improved editions of the model have been released. For given location, time and date, IRI provides monthly averages of the electron density, electron temperature, ion temperature, and ion composition in the ionospheric altitude range. In this work we choose IRI-2012 to obtain the TEC.

IRI-2012 estimates the TEC by integrating the electron density profile from the lower boundary to a specified upper boundary of ionosphere. The electron density profile is divided into the bottomside and topside parts with the F2 peak height hmF2. The topside profile is more important than bottomside because of its impact on TEC [11]. In this paper, The IRI TEC is calculated from the website http://omniweb.gsfc.nasa.gov/vitmo/iri2012_vitmo.html.

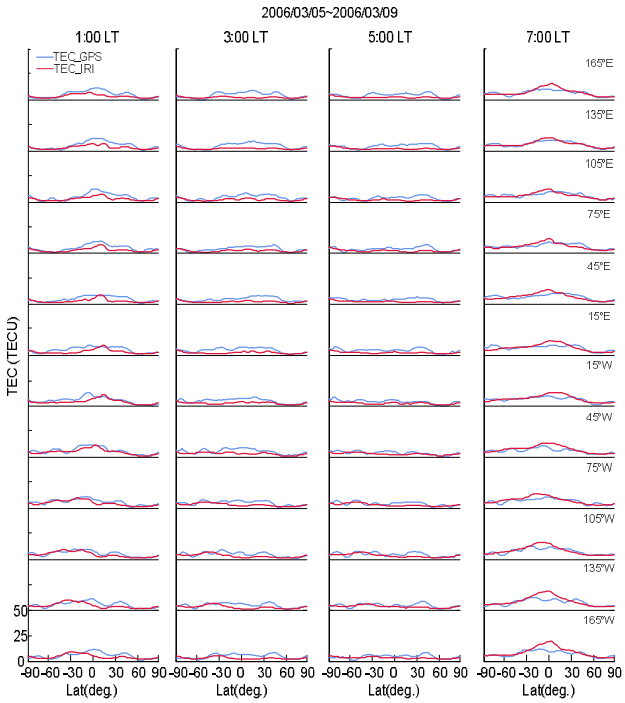
2.2 TEC derivation with GPS

GPS TEC data are maintained and monitored by the International GNSS service (IGS). The Ionosphere Working group started the routine generation of the combine Ionosphere Vertical Total Electron Content

(TEC) maps in June 1998. This has been the main activity so far performed by the four IGS Ionosphere Associate Analysis Centers (IAACs): CODE (Center for Orbit Determination in Europe, Astronomical Institute, University of Berne, Switzerland), ESOC (European Space Operations Center of ESA, Darmstadt, Germany), JPL (Jet Propulsion Laboratory, Pasadena, California, U.S.A), and UPC (Technical University of Catalonia, Barcelona, Spain). Independent computation of rapid and final VTEC maps is used by the each analysis centers: Each IAACs compute the rapid and final TEC maps independently and with different approaches including the additional usage of GLONASS data in the case of CODE [12]. CODE using data from about 200 GPS/GLONASS sites of the IGS and other institutions. The vertical total electron content (VTEC) is modeled in a solar-geomagnetic reference frame using a spherical harmonics expansion up to degree and order 15.

3. Results and discussions

Figure1 shows the median TEC from 5 March 2006 to 9 March 2006 for different local times and longitudes. IRI TEC agrees with GPS TEC very well at high latitudes. They are generally in agreement even at low latitudes for the period from evening to morning. However, differences are found from 11:00-17:00 LT at low latitudes. It can be seen that the north-south asymmetry has remarkable effect on both IRI TEC and GPS TEC, especially in the equatorial ionization anomaly (EIA). The strength of EIA crest is obviously higher in north than in south about IRI TEC, it reaches ~11 TECU around 15° E longitude at 13:00 LT. Meanwhile, EIA crest in daytime is generally exaggerated and the noon-bite out is deep in the IRI TEC than GPS TEC, the difference of noon-bite is about 12 TECU around 105° E longitude at 13:00 LT.



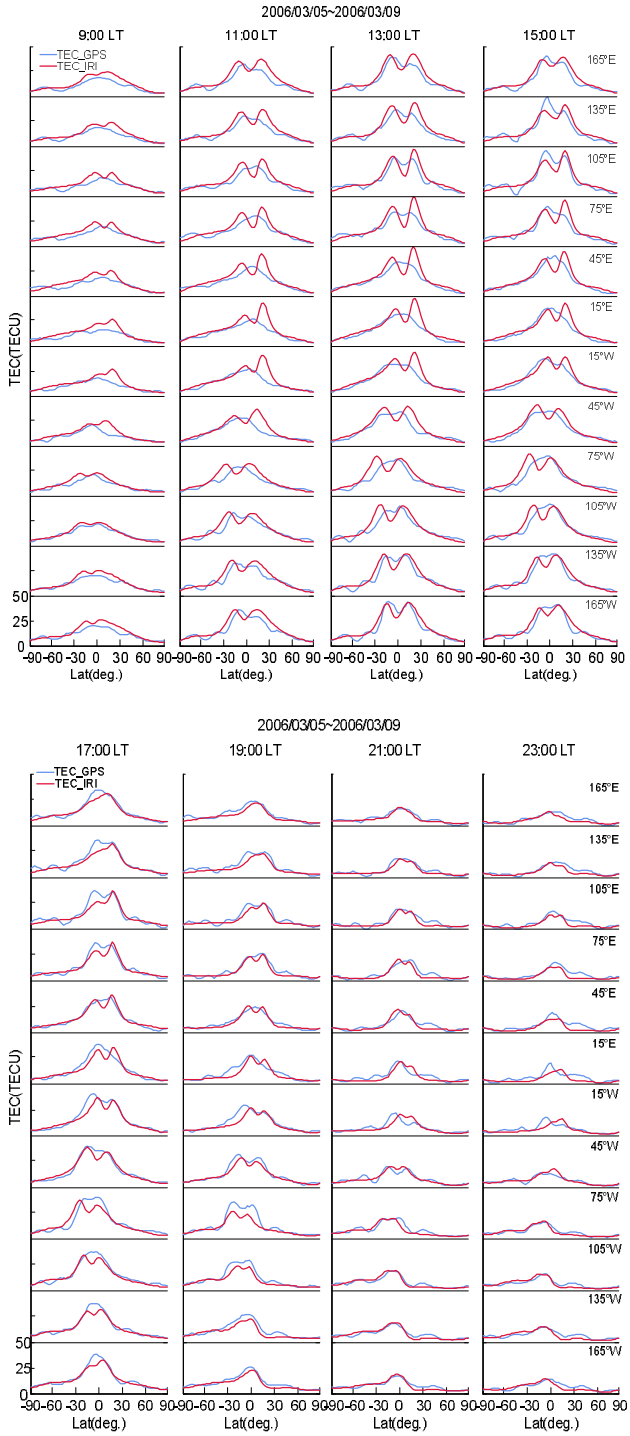


Figure 1. Comparison of IRI TEC and GPS TEC from 5 March to 9 Marth in 2006.

4. Conclusion

This paper studies the comparison of global TEC between IRI TEC and GPS TEC in the spring of 2006. IRI TEC agrees with GPS TEC very well at high latitudes. They are generally in agreement even at low latitudes for the period from evening to morning. However, the equatorial ionization anomaly in daytime is generally exaggerated and the noon bite out is deep in the IRI TEC than GPS

TEC. Another difference in equatorial ionization anomaly is the north-south asymmetry of TEC at the anomaly crests. The main differences are found from 11:00-17:00 LT at low latitudes. It can be seen that the north-south asymmetry has remarkable effect on both IRI TEC and GPS TEC, especially in EIA. The strength of EIA crest is obviously higher in north than in south about IRI TEC, it reaches ~11 TECU around 15° E longitude at 13:00 LT. Meanwhile, EIA crest in daytime is generally exaggerated and the noon-bite out is deep in the IRI TEC than GPS TEC, the difference of noon-bite is about 12 TECU around 105° E longitude at 13:00 LT.

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6. References

1. Bilitza, D., M. Hernandez-Pajares, J. M. Juan, and J. Sanz, Comparison between IRI and GPS-IGS derived electron content during 1991-97 , *Phys. Chem. Earth*, Vol.24, No.4, 1999, pp. 311 319.

2. L.F Huang, J. Huang, J.S Wang, Y. Jiang, B.C Deng, K. Zhao, G.G Lin, Analysis of the north south asymmetry of the equatorial ionization anomaly around 110°E longitude , *Journal of Atmospheric and Solar-Terrestrial Physics,* Vol.102, 2013, pp. 354 361.

3. Arikan, F.H., Erol, C.B. and Arikan, O., Regularized estimation of vertical total electron content from Global Positioning System data , *J. Geophys. Res.-Space Phys.,* Vol.108, 2003, pp. 1469 1480.

4. Lanyi, G.E. and Roth,T., A comparison of mapped and measured total ionospheric electron content using global positioning system and beacon satellites observations , *Radio Sci.,* Vol.23, 1988, pp. 483 492.

5. Xue, J.C., Song, S.L. and Zhu, W.Y., Global ionosphere model based on BDS/GPS dual-system observations , *SCIENTIA SINICA Physica, Mechanica & Astronomica,* Vol.45, 2015, pp. 079505.

6. Wang, C., Zhang, M., Xu, Z.W., Mao, C. and Chen, C., A new approach of TEC retrieval from the space-borne SAR , *Chinese J. Geophysics,* Vol.57, 2014, pp. 3570 3576.

7. Xiong, B., Wan, W.-X., Ning, B.-Q., Hu, L.-H., Ding, F., Zhao, B.-Q. and Li, J.-Y, Investigation of mid- and low-latitude ionosphere based on BDS, GLONASS and GPS observations , *Chinese Journal Geophysics,* Vol.57, 2014, pp. 3586 3599.

8. Shim, J.S., Kuznetsova, M., Rastatter, L., Bilitza, D., Butala, M. and Codrescu, M. etal, Systematic Evaluation of Ionosphere/Thermosphere (IT) Models in Modeling the Ionosphere-Thermosphere System , *Modeling the Ionosphere-Thermosphere System*, 2014, doi:10.1002/9781118704417.ch13.

9. Bilitza, D. and Reinisch, B.W., International reference ionosphere 2007: improvements and new parameters , *J. Geophys.* Adv. Space Res., Vol.42, 2008, pp. 599 609.

10. http://www.irimodel.org/

11. Bilitza, D. and K. Rawer, International Reference Ionosphere , in *The Upper Atmosphere—Data Analysis and Interpretation, Springer-Verlag, Berlin, Heidelberg,* 1996, pp. 735 772.

12. Dow, J. M., R. E. Neilan, and C. Rizos, The International GNSS Service in a changing landscape of Global Navigation Satellite Systems , *J. Geod.,* Vol.83, 2009, pp.191 198.