International Beacon Satellite Symposium BSS-2016
Trieste, Italy

Comprehensive assessment of ionospheric electron content models: Methodology

Manuel Hernández-Pajares*[1], David Roma-Dollase[1,2], Raül Orús-Pérez[3], Alberto García-Rigo[1], Andrzej Krankowski[4]

[1] UPC-IonSAT, Departament de Matemàtiques, Mod. C3 Campus Nord UPC, Jordi Girona 1-3, 08034-Barcelona, SPAIN (E-mail: manuel.hernandez@upc.edu, alberto.garcia.rigo@upc.edu)

[2] Dept. Electronics, Universitat de Barcelona, Barcelona, Spain
(E-mail:droma@el.ub.edu)

[3] ESA/ESTEC, Noordwijk, The Nethernlands
(E-mail:droma@el.ub.edu)

[4] Space Radio-Diagnostic Research Centre, University of Warmia and Mazury in Olsztyn, ul. Prawocheńskiego 9, 10-720 Olsztyn, POLAND (E-mail: kand@uwm.edu.pl)

ABSTRACT

During the last two decades different models of the ionospheric electron content, mainly based on GNSS measurements, have been proposed, with different approaches and different strong points (see for instance Bust & Mitchell 2008 [1], and Hernández-Pajares et al. 2011 [2]). The starting of the generation, and especially combination of Global Ionospheric VTEC Maps (GIMs) in the International GNSS Service context, created the need, in 1998, of developing a ranking strategy, simple enough to be automatically applied, and realistic enough to produce a good (higher integrity and high accuracy) combined International GNSS Service (IGS) GIM. Indeed, the so called "Self-consistency test" (see for instance Hernández-Pajares 2004[3] and Orús et al. 2005[4], 2007[5]), provided a reference truth (or "golden standard"), measured with very high precision (with typical errors below 0.1 TECU) from the dual-frequency geometry-free combination of carrier phases measured from permanent receivers. It consists on the variation of STEC between points of the same phase-continuous arch transmitter-satellite, separated up to few hours but at the same elevation. Later on a variation of the "Self-consistency test" was proposed, taking the STEC difference of the given observation regarding to the observation with highest elevation, being the first measurement the one mainly affected by any kind of errors (like the ionospheric mapping function error). This kind of assessment was called dSTEC or STEC-variation test (see for instance Feltens et al. 2011[6]). On the other hand, during the previous decade, Ho et al. (1997) [7] already proposed the usage of dual-frequency altimeter data to directly validate VTEC values directly measured over the oceans.

In this context we will summarize as well the main advantages of applying both complementing assessment strategies, STEC-variation and VTEC tests:

1) They can be applied externally to the ionospheric electron content models, which typically don't ingest altimeter data (VTEC test), and by selecting representative GNSS receivers not used in the model computation (STEC-variation test).
2) VTEC test directly assess the quality of the instantaneous Vertical TEC provided by the different models on worse conditions, over the oceans and seas, typically far from the most part of GNSS receivers used in their estimation.
3) STEC-variation test, typically assess the quality of the Slant TEC, sensitive then to the mapping function quality. Moreover it includes as well regions better sounded. And the capability of the ionospheric model to describe the time variations of the electron content is assessed as well.
4) The reference measurements for both STEC-variation and VTEC tests are available worldwide for more than one Solar Cycle, and allow a deep multi-scale temporal assessment, in different ionospheric and space weather conditions (this will be illustrated with an executive summary of the corresponding assessments done so far: in particular Hernández-Pajares et al. 2004 [3], Orús-Pérez et al. 2005[4], 2007[5], Hernández-Pajares et al. 2009 [8] and Hernández-Pajares et al. 2016[9]).

Additional details of the VTEC and STEC-variation assessment will be discussed, like the negligible, but scientifically interesting influence of the protonospheric electron content above the altimeters, and the potential effect of the mapping function used for each model, respectively. Moreover a short comparison on other assessment techniques (like Rovira et al. 2015, [10]), not showing the advantages of external and direct evaluation (points 1 to 3 above) will be commented as well.

Key words: Ionospheric electron content models, GNSS

References

[1] Bust, G. S., & Mitchell, C. N. (2008). History, current state, and future directions of ionospheric imaging. Reviews of Geophysics, 46(1).

[7] Ho, C. M., Wilson, B. D., Mannucci, A. J., Lindqwister, U. J., & Yuan, D. N. (1997). A comparative study of ionospheric total electron content measurements using global ionospheric maps of GPS, TOPEX radar, and the Bent model. Radio Science, 32(4), 1499-1512.

[6] Feltens, J., Angling, M., Jackson-Booth, N., Jakowski, N., Hoque, M., Hernández-Pajares, M., ... & Zandbergen, R. (2011). Comparative testing of four ionospheric models driven with GPS measurements. Radio Science, 46(6).

[3] Hernández-Pajares, M. (2004, March). IGS Ionosphere WG Status Report: Performance of IGS Ionosphere TEC Maps-Position Paper. In IGS Workshop, Bern.

[2] Hernández-Pajares, M., Juan, J. M., Sanz, J., Aragón-Àngel, À., García-Rigo, A., Salazar, D., & Escudero, M. (2011). The ionosphere: effects, GPS modeling and the benefits for space geodetic techniques. Journal of Geodesy, 85(12), 887-907.

[8] Hernández-Pajares, M., Juan, J. M., Sanz, J., Orus, R., Garcia-Rigo, A., Feltens, J., Komjathy A., Schaer, S. & Krankowski, A. (2009). The IGS VTEC maps: a reliable source of ionospheric

information since 1998. Journal of Geodesy, 83(3-4), 263-275.

[9] Hernández-Pajares, M., Roma-Dollase, D. , Krankowski, A., Ghoddousi-Fard, R., Yuan, Y., Li, Z., Zhang H., Shi, C., Feltens, J., Komjathy, A., Vergados, P., Schaer, S.C., Garcia-Rigo, A., Gómez-Cama, J. M. (2016). Comparing performances of seven different global VTEC ionospheric models in the IGS context, IGS Workshop, February 2016, Sydney, Australia.

[4] Orus, R., Hernández-Pajares, M., Juan, J. M., & Sanz, J. (2005). Improvement of global ionospheric VTEC maps by using kriging interpolation technique. Journal of Atmospheric and Solar-Terrestrial Physics, 67(16), 1598-1609.

[5] Orus, R., Cander, L. R., & Hernández-Pajares, M. (2007). Testing regional vertical total electron content maps over Europe during the 17–21 January 2005 sudden space weather event. Radio Science, 42(3).

[10] Rovira-Garcia, A., Juan, J. M., Sanz, J., & Gonzalez-Casado, G. (2015). A worldwide ionospheric model for fast precise point positioning. Geoscience and Remote Sensing, IEEE Transactions on, 53(8), 4596-4604.