UPC contributions to GNSS monitoring of ionosphere in the frame of the IGS Iono-WG

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Abstract

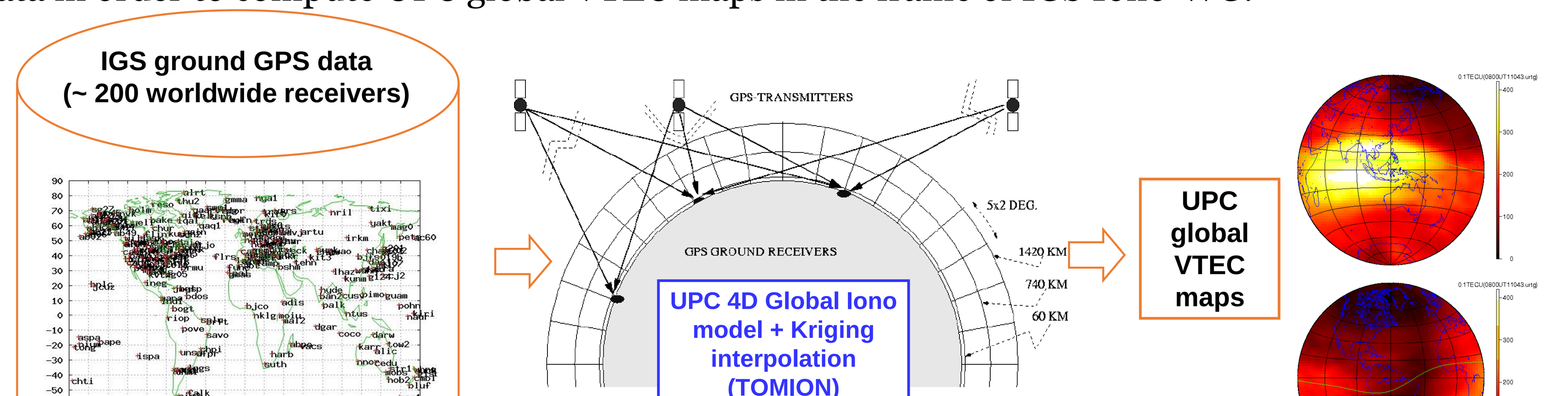
UPC has been acting as Ionosphere Associate Analysis Center (IAAC) from the beginning of the IGS Iono-WG activities on 1st June, 1998, providing multiple products on GNSS monitoring of ionosphere and also assuming its chairmanship for 5 years (2002 to 2007), as the result of the common work of the co-authors of this presentation.

The recently formed UPC-IonSAT research group has not only continued providing rapid, final and 2-days ahead predicted Global Ionospheric Maps (GIMs) at 2-hour time resolution in IONEX format labelled UPCG, UPRG and U2PG respectively) but also real time GIMs (labelled URTG) and 15-minute and 1-hour time resolution GIMs considering rapid latencies (labelled UQRG and UHRG, respectively).

Such products have been generated using the TOMION SW for ionospheric modelling and precise positioning. TOMION has evolved from 1998 until nowadays in order to provide the above-mentioned recent products but also to improve the performance of the previously existing ones. This also has led to a reprocessing campaign. It is also worth mentioning that an improved Kriging interpolation technique, combined with the global tomographic modelling ([Orús et al., 2005 and Hernández-Pajares et al. 1999]) has recently enabled a boost in the performance for all existing products.

TOMION: Computation of global VTEC maps based on GPS data

- The TOmographic Model of the IONospheric electron content (TOMION) is fed with global GPS data in order to compute UPC global VTEC maps in the frame of IGS Iono-WG.



$$L_I = S + B_I \simeq \sum_{i=1}^{n} N_{e,i} \Delta l_i \quad (1)$$

Fig. 1. Layout summarizing the global VTEC computation from ground GPS data by means of the UPC TOMION software, including the main tomographic equation solved for (data: ionospheric combination of carrier phases L_I , and length intersection within each voxel, Δl_i; unknowns: its ambiguity B_I, the STEC, S, which includes the mean electron density within each given voxel, $N_{e,i}$).

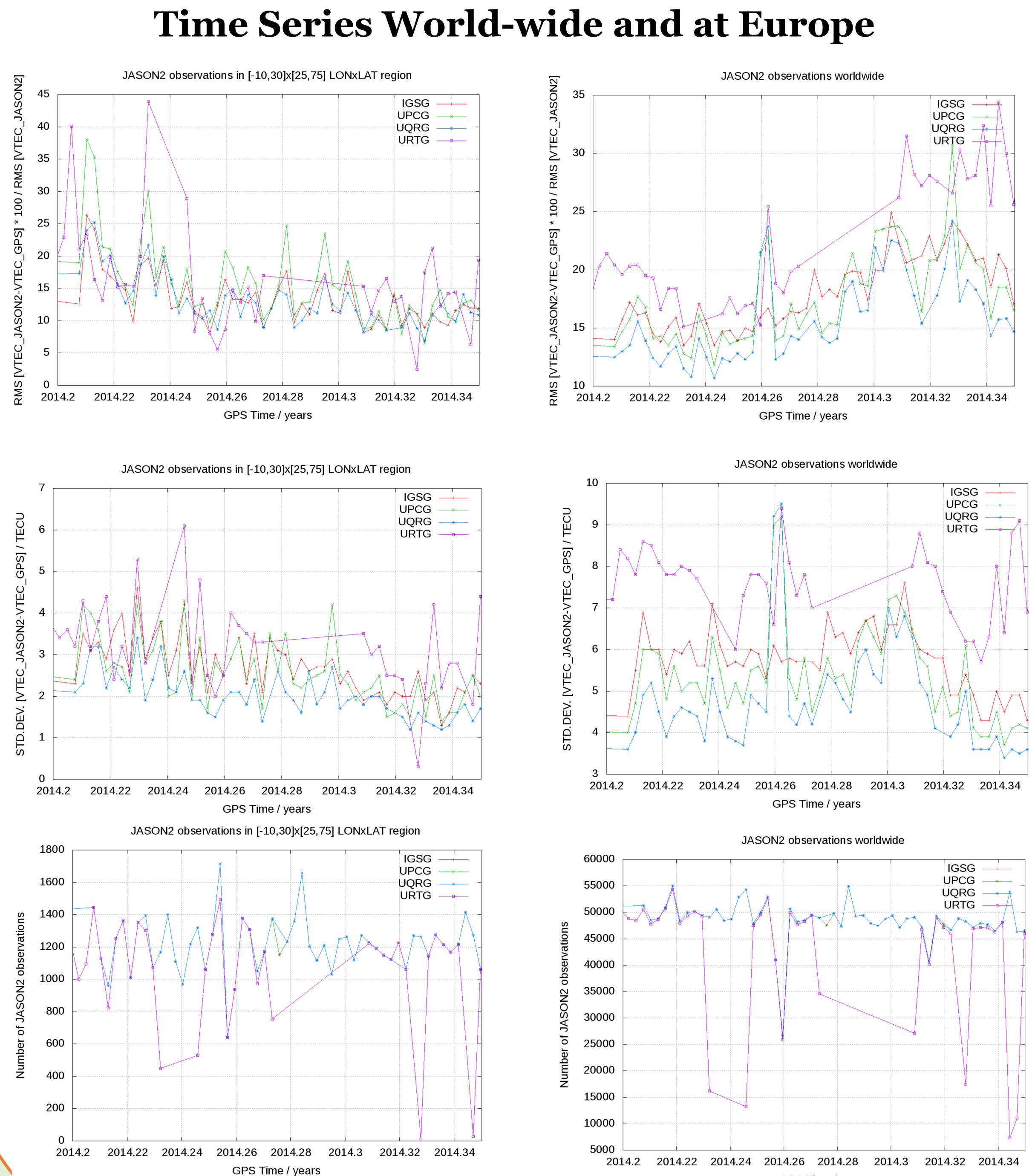
Performance against JASON2 altimeter data

A recent period, from day of year 001, 2013 to 150, 2014 has been analyzed to show the performance of the most recent UPC products: real time global ionospheric maps (labelled URTG), global ionospheric maps at 15 minutes time resolution (UQRG) and at 1 hour time resolution (UHRG; computed from UQRG files). The products shown as reference are the combined and UPC Final IGS products (IGSG and UPCG, respectively) as well as the UPC Rapid IGS product (UPRG).

Performance results on the above mentioned IGS products will be given by considering as reference VTEC direct measurements from JASON2 dual-frequency altimeter. JASON observations provide direct and independent VTEC measurements over the seas in spite they are affected by an small positive offset of few TECU with respect to the IGS products ([Azpilicueta et al. (2008) and Hernandez-Pajares (2004)]) which does not compromise its usage for assessment. GPS TEC observations for receiver-satellite pairs include the small plasmaspheric contribution, in contrast to the case of JASON that orbits at an altitude of ~= 1300km. Second, this is a pessimistic scenario because JASON direct measurements are compared with interpolated values at the same exact location derived from the nearby grid points of the VTEC map being validated. And it is likely that even the VTEC at these grid points had to be interpolated from insufficient real data due to the lack of permanent GNSS stations over the oceans.

The following figures show (1) time series of the Bias and St.Dev. of the differences between the above-mentioned IGS products and the JASON VTEC determinations, (2) the boxplots showing the important statistics of a sample graphically by comparing the position of the quartiles, and (39 (2) the Bias and St. Dev in latitude bins of two degrees showing the latitudinal behavior.

Time Series World-wide and at Europe



Boxplots analysis

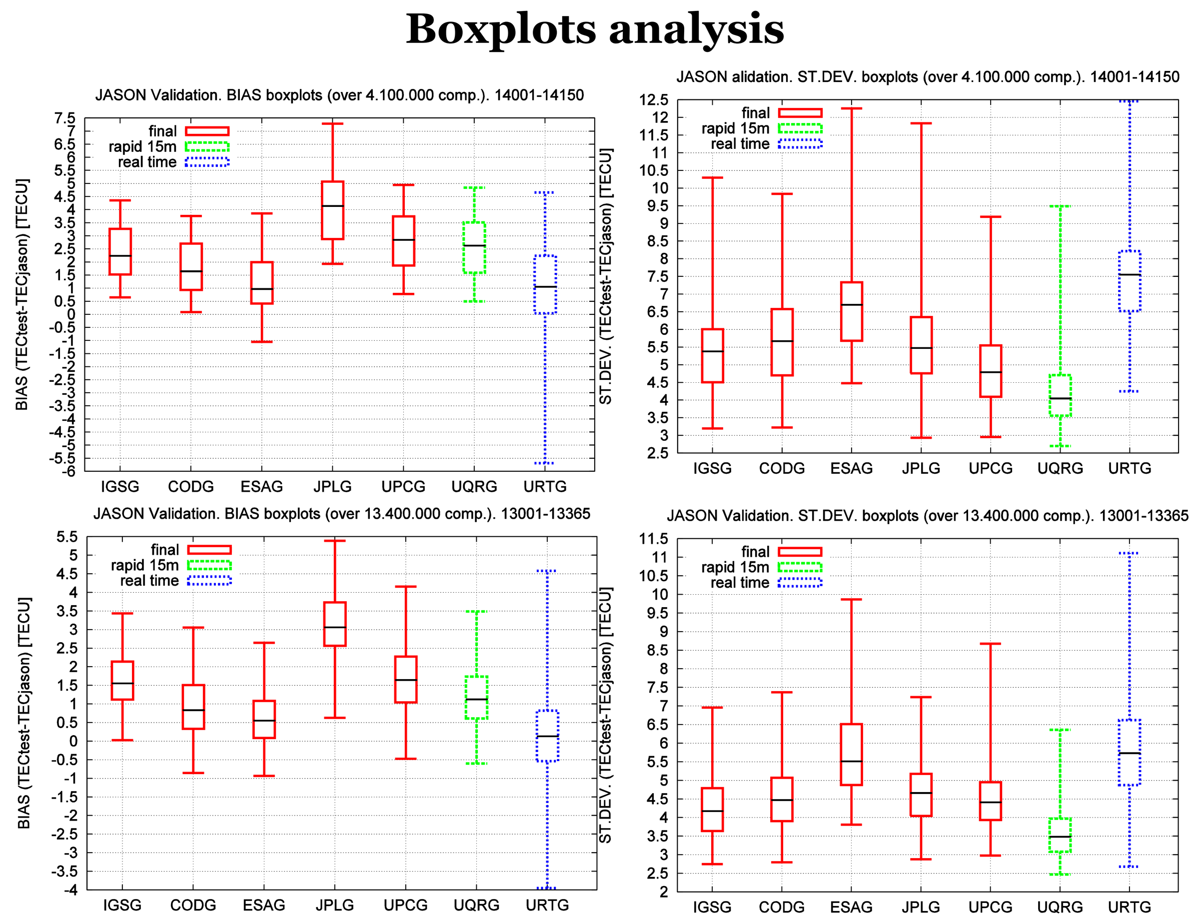


Fig. 3: Bias (left) and standard deviation (right) boxplots of the differences between the test data and the JASON reference data for the periods 001/2013 to 365/2013 and 001/2014 to 150/2014.

Fig. 1: RMS (top), standard deviation (middle) and number of JSAON observations (bottom) of the differences between the test data and the JASON reference data. The assessed values were for the European region (left) and world-wide (right) for the period 001/2014 to 150/2014.

Latitudinal behavior plots

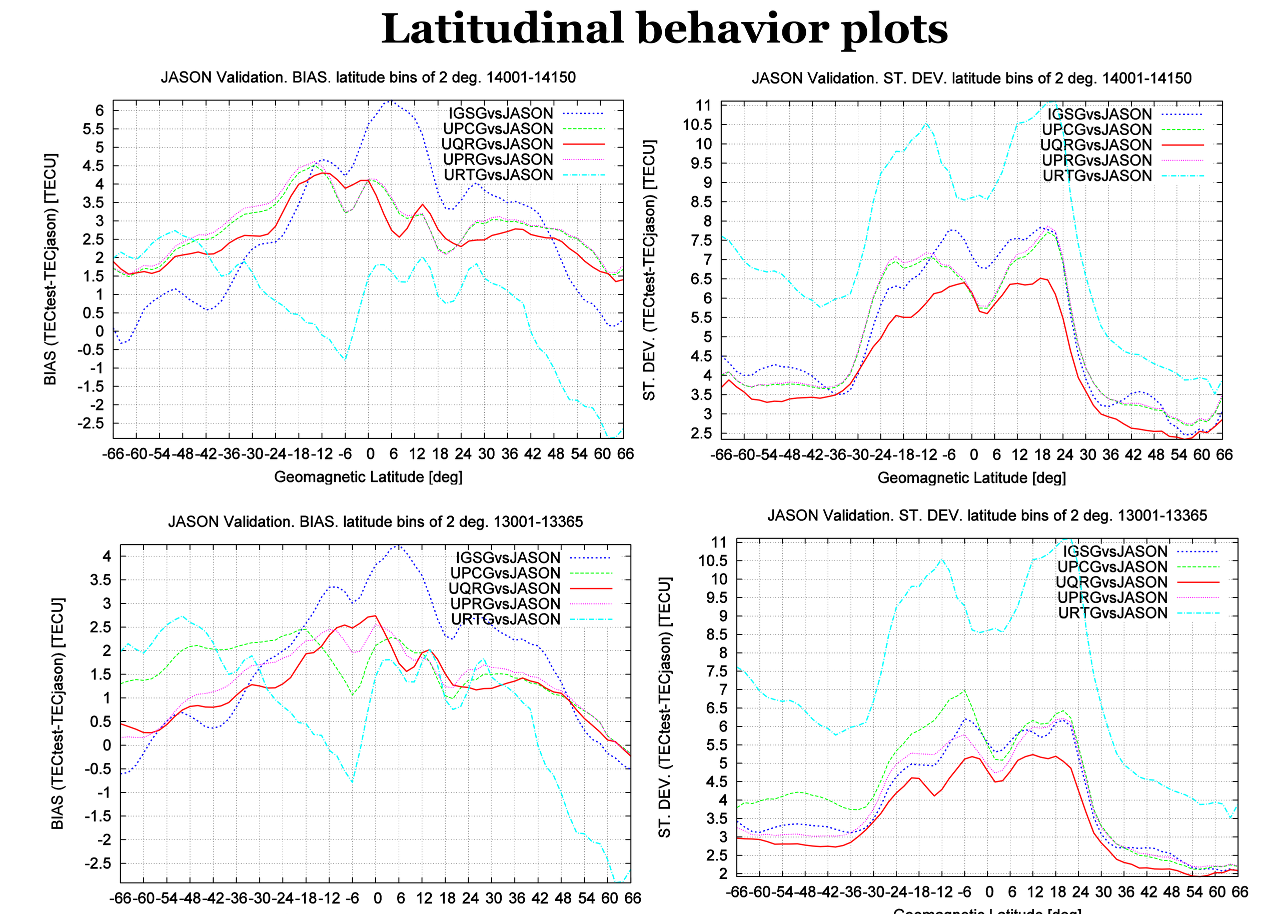


Fig. 4: Bias (left) and standard deviation (right) of the differences between the test data and the JASON reference data. The assessed values were in two degrees geomagnetic latitude bins for the periods 001/2013 to 365/2013 and 001/2014 to 150/2014.

Conclusions and next steps

The product performance of UQRG (compared with direct VTEC measurements with altimeters) is systematically better than the other IGS maps in terms of St. Dev and RMS, in terms of the latitudinal behavior and lower disperson in terms of statistical distribution, even though the latency of such product is rapid (1 day, in IGS nomenclature) instead of final (several days). Regarding the URTG product, the performance is reasonable since the number of permanent NTRIP GNSS datastreams world-wide very limited (about 70). As for next steps, the computation of final 15-minute time resolution GIMs (UQCG) and final hourly GIMs (UHCG) is envisaged for the near future considering 3-4 days latency with available data of more receivers. This shall also enable a significant improvement in final UPCG files thanks to considering an increased number of GNSS stations. In addition, UPC-IonSAT is also working on improving real time URTG GIMs by increasing the number of NTRIP datastreams being considered in the computations (increased last week to almost 200 datastreams), and it also keeps in mind the possibility to provide very precise real time GIMs on specific regions with high density of GNSS streams (such as Europe).

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References

Azpilicueta, F. and C. Brunini (2008), Analysis of the bias between TOPEX and GPS vTEC determinations, *J. of Geodesy*, 83, Issue 2, 121-127

Orús, R. (2005), Contributions on the improvement, assessment and application of the Global Ionospheric VTEC Maps computed with GPS data, *Ph.D. dissertation*. Doctoral Program in Aerospace Science & Technology, Universitat Politècnica de Catalunya, Barcelona, Spain.

Hernández-Pajares, M., J.M. Juan, J.Sanz, A. García-Rigo, J. Feltens, A. Komjathy, S.C. Schaer, and A. Krankowski (2009), The IGS VTEC maps: a reliable source of ionospheric information since 1998, *Special IGS Issue of Journal of Geodesy*, 83:3-4, 263-275.

Hernandez-Pajares (2004), IGS Ionosphere WG status report: performance of IGS Ionosphere TEC Maps -Position Paper-, IGS Technical Meeting, Bern, Switzerland.