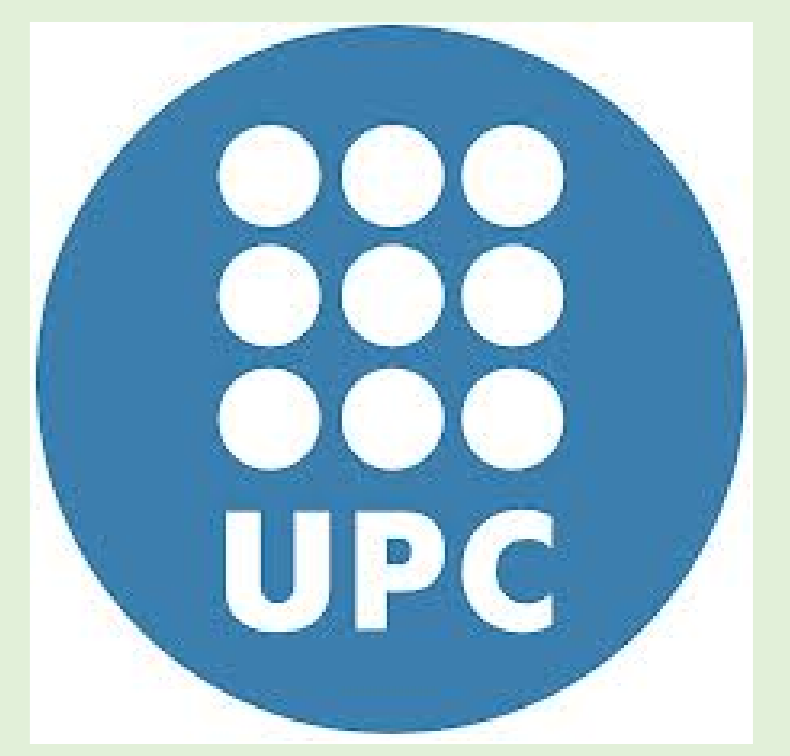


# UPC contributions to GNSS monitoring of ionosphere in the frame of the IGS Iono-WG



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## Abstract

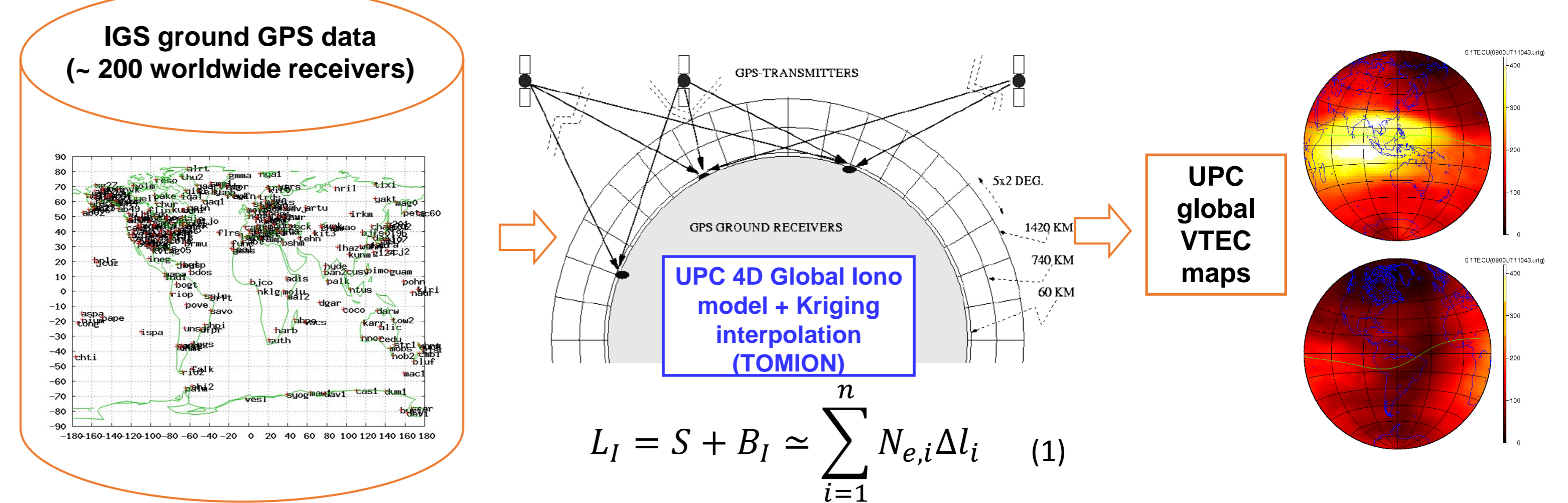
UPC has been acting as Ionosphere Associate Analysis Center (IAAC) from the beginning of the IGS Iono-WG activities on 1st June, 1998, providing multiple products on GNSS monitoring of ionosphere and also assuming its chairmanship for 5 years (2002 to 2007), as the result of the common work of the co-authors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



**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  $L_1$ , and length intersection within each voxel,  $\Delta l_i$ ; unknowns: its ambiguity  $B_1$ , the STEC,  $S$ , which includes the mean electron density within each given voxel,  $N_{e,i}$ ).

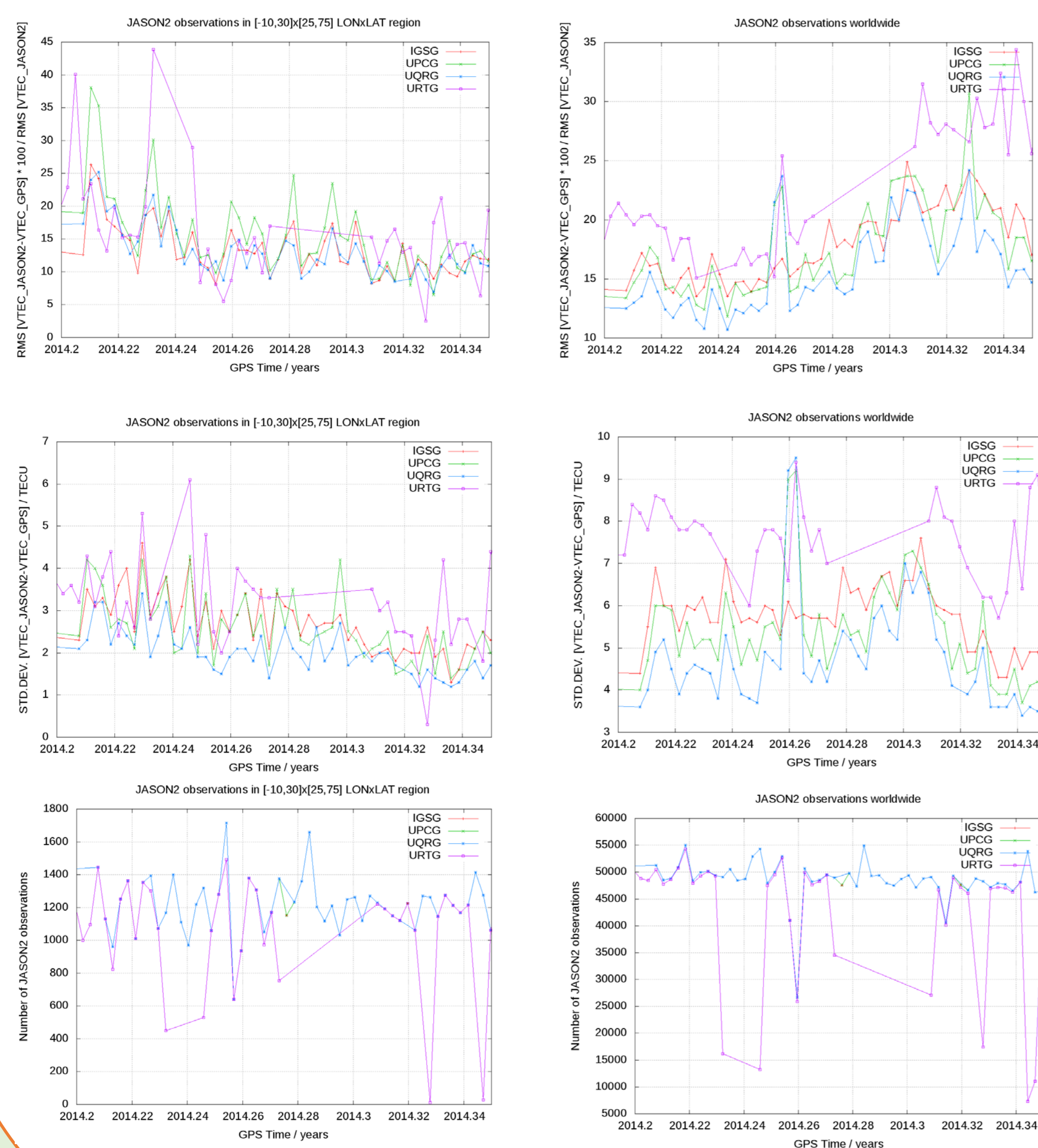
## Performance against JASON2 altimeter data

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 directly 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).

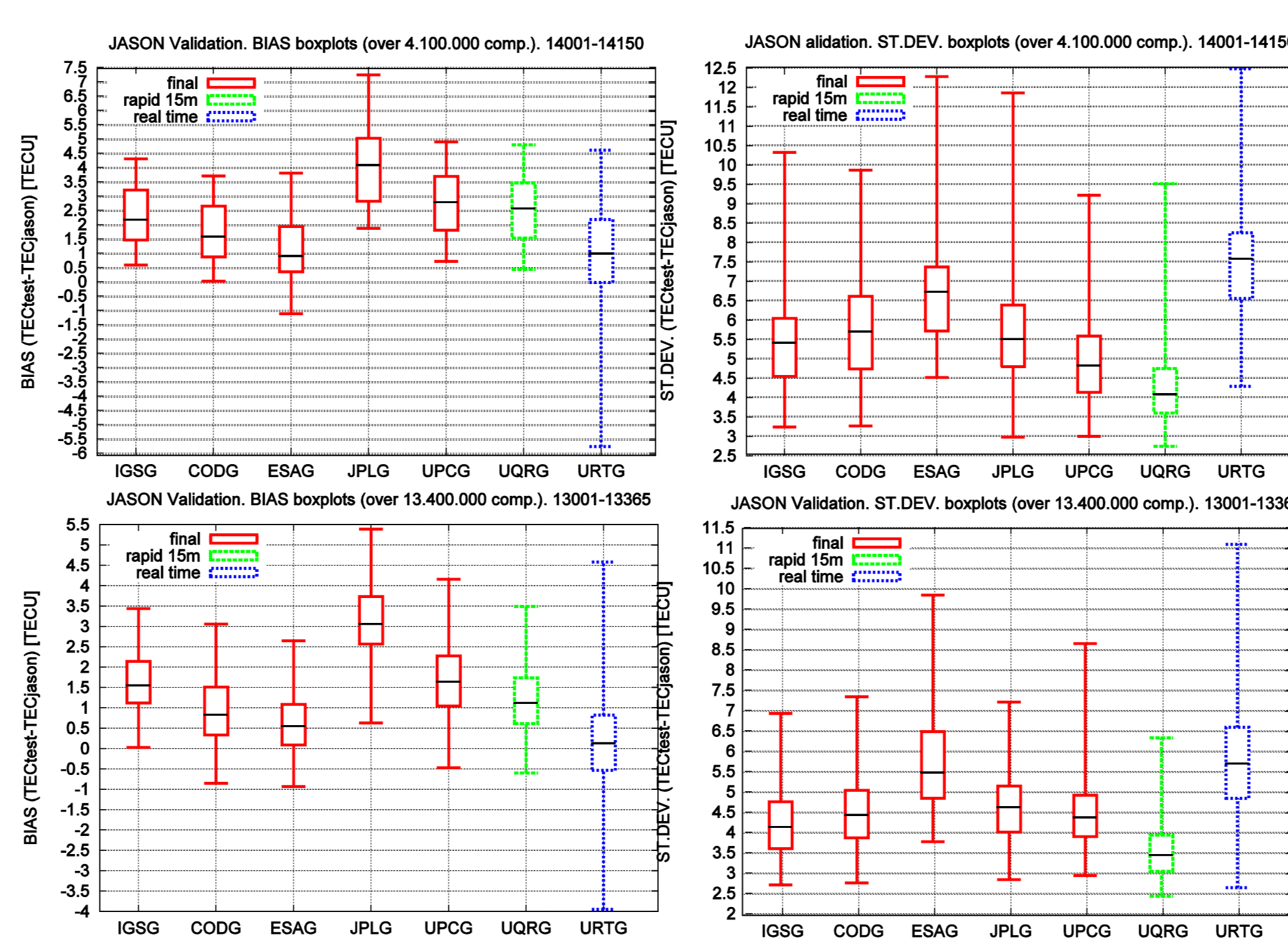
Performance results on the above-mentioned IGS products are given by considering as reference VTEC direct measurements from JASON2 dual-frequency altimeter. JASON observations provide direct and independent VTEC measurements over the seas in spite they are affected by a small positive offset of few TECUs with respect to the IGS products ([Azpilicueta et al. (2008) and Hernandez-Pajares (2004)]) which does not compromise its usage for assessment. GPS VTEC observations for receiver-satellite pairs include the small plasmaspheric contribution, in contrast to the case of JASON that orbits at an altitude of  $\approx 1300$ km. Note that this is a pessimistic scenario since 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 (3) the Bias and St. Dev in latitude bins of two degrees showing the latitudinal behavior.

### Time Series World-wide and at Europe

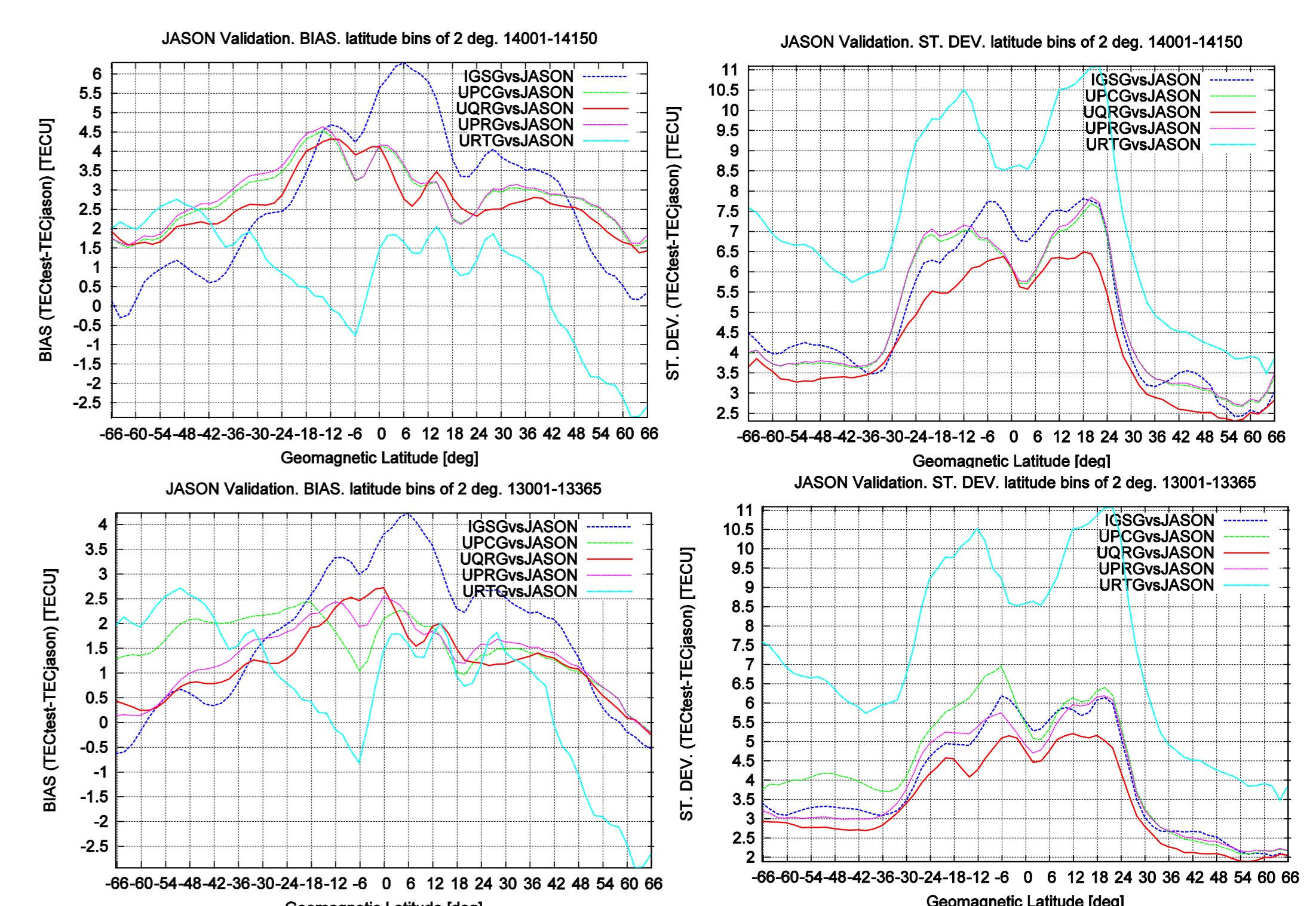


### Boxplots analysis



**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 (bottom) and 001/2014 to 150/2014 (top). The red ones correspond to Final IGS products (final latency of several days), the green one corresponds to UQRG product (rapid latency after one day), the blue one corresponds to URTG product (in real time; computed with very limited number of NTRIP GNSS datastreams (about 70)).

### 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 (bottom) and 001/2014 to 150/2014 (top).

**Fig. 2:** RMS (top), standard deviation (middle) and number of JASON 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.

## Conclusions and next steps

The product performance of UQRG (compared with direct VTEC measurements with altimeters; and thus UHRG as well) is systematically better than the other IGS maps in terms of St. Dev and RMS, in terms of the latitudinal behavior and has lower dispersion in terms of statistical distribution, even though the latency of such product is rapid (one 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 is very limited (about 70). As for next steps, the computation of final 15-minute time resolution GIMs (to be labelled UQCG) and final hourly GIMs (to be labelled UHCG) is envisaged for the near future considering 3-4 days latency with availability 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 the week prior to IGS Workshop 2014 to almost 200 datastreams), and the authors also keep in mind the possibility to provide very precise real time GIMs for specific regions with high density of GNSS datastreams (such as for Europe).

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