REAL TIME APPLICATION OF TOMION MODEL: FIRST GLOBAL RESULTS

ORUS, R.*,[1], HERNANDEZ-PAJARES, M.*, JUAN, J.M.*, SANZ, J.*, ARAGON-ANGEL, A.*, GARCIA-RIGO, A.*

* Research group of Astronomy and Geomatics (gAGE/UPC)
Universitat Politècnica de Catalunya (UPC)
Campus Nord UPC, 08034 Barcelona, Spain
[1] Wave Interaction & Propagation Section (ESA-ESTEC), Noordwijk, Netherlands.

1. INTRODUCTION

Since the first development of the TOMION (TOmographic Model of the IONosphere), in 1995, gAGE/UPC has been improving the performance and reliability of this technique. The TOMION kernel relies on the computation of the ionospheric electron density by means of using a 4D model of the ionosphere. At the beginning the technique was mainly focused on ionospheric determination from a single or few stations using a 2-layer tomographic approach, see [4] and [8]. Further developments lead to the use of TOMION as a global ionospheric scanner, see [6], allowing the use of TOMION to produce Global Ionospheric Maps (GIMs) for the International GNSS Service (IGS) jointly with CODE (University of Bern), EMR (Energy mines and Resources, NRCAN), ESA (European Space Agency) and JPL (Jet Propulsion Laboratory) since 1st June 1998. In parallel to this activity, the TOMION capabilities were increased, and the use of more than 2 layers was a natural extension of the model, see [5]. However, other approaches were introduced, and as a result of that effort the Improved Abel technique, for electron density profile retrieving, was developed, see [7]. This technique was based on the separability hypothesis, which overtook the limitations of the spherical hypothesis for electron density retrieval.

In the last years, the TOMION has been improved in all the mentioned fields by gAGE/UPC. This includes the development of the improved Abel inversion and assimilation techniques using ionosonde data; see [2] and [1], the improvement of the Global Ionospheric interpolation by means of Kriging technique, see [9] and more recently the inclusion of prediction capability to 2 days ahead, see [3]. Along with these techniques, the capacity of the gAGE/UPC to verify and test the new improvements has been highly increased, developing techniques from GNSS data itself to using external data, such as altimeter, ionosondes and Langmuir probe.

Therefore, the natural step forward for the TOMION grow was to add real time capability for ionospheric determination. In this sense, the use of the IGS Real Time network, jointly with the BKG caster software, opens the possibility to merge all the know-how to develop a real time open product of the ionosphere for the scientific community.

2. IMPROVED TOMION APPLICATIONS

2.1. Testing the ionospheric products of TOMION

Since 1998 the gAGE/UPC is participating in the IGS ionospheric working group as a computation and analysis centre. The use of different algorithms to test the GIMs has become a routine task inside the working group. These tests are generally done with altimeter data (TOPEX, JASON and ENVISAT missions) and with the GPS data itself, using the so-called self-consistency test developed in gAGE/UPC. However, in order to test the different capabilities of the TOMION, for instance the electron density profiles, other approaches to compute the goodness of the method have been used. Thus, since the TOMION only gives electron density profiles in the region where an occultation happens, the concept of collocation of the electron density profile has to be used in order to test key parameters of the ionosphere that can be obtained from the electron density profiles, see Figure 1. In this sense, with the use of the separability hypothesis the extension of the tests is limited to the neighborhood (few thousands of km) of the reference data.

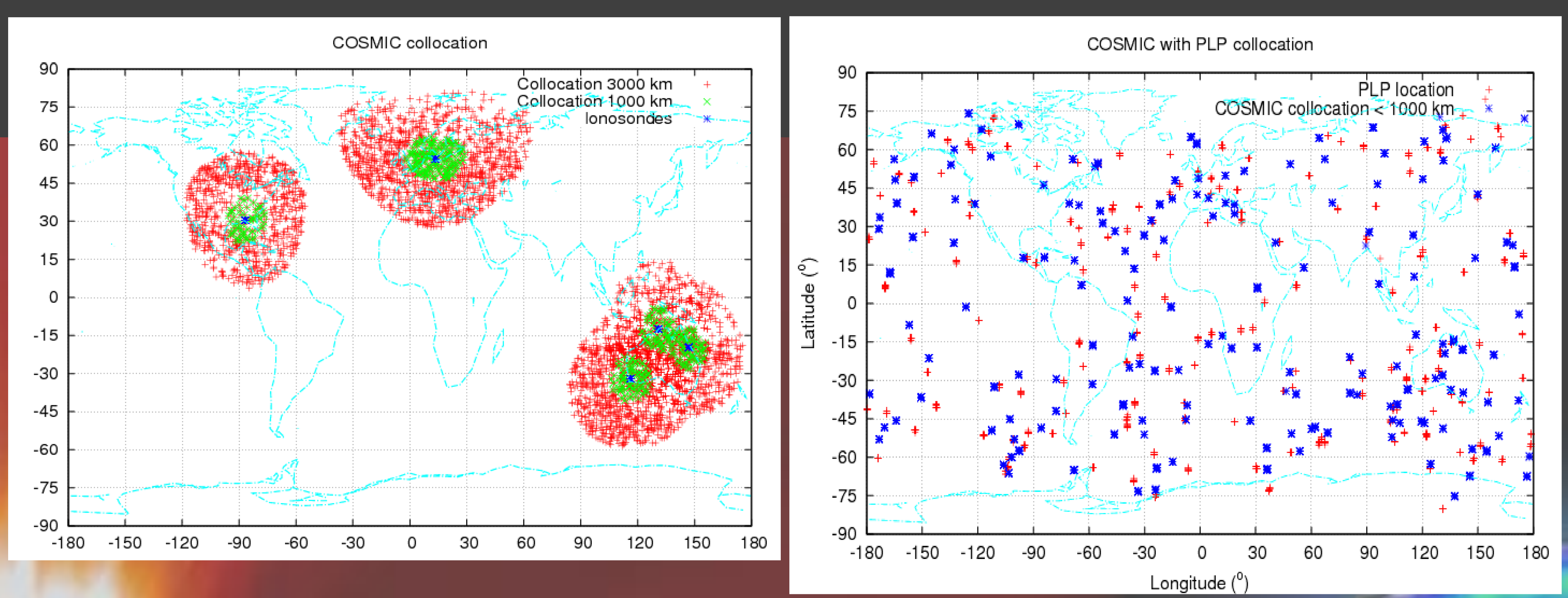

Figure 1: Collocated data for FORMOSAT-3/COSMIC satellites for testing with ionosonde (left panel) and PLP data (right panel) for the year 2006.

2.2. Real Time Ionosphere

The real time streams, containing the permanent GPS receiver measurements, are gathered from the IGS and EUREF Real time networks with the use of the BKG Ntrip Client software of the Federal Agency for Cartography and Geodesy (BKG) (http://www.bkg.bund.de). In this sense, for this first prototype the streams of about 50 stations worldwide distributed, see Figure 2, are gathered in order to compute the 2-layer voxel model of the ionospheric electron content, with a resolution of 7°x6° in local time and latitude.

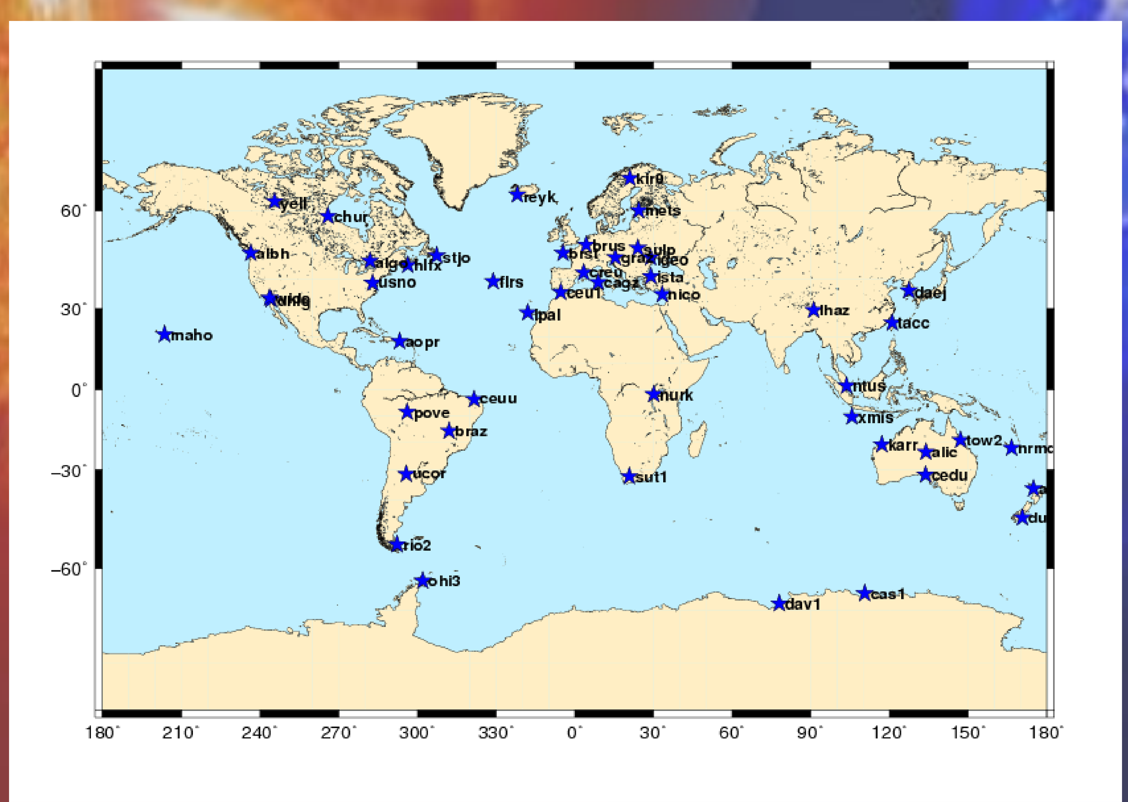

Figure 2: Map of the real time IGS GPS streams used for ionospheric determination.

After the data have been processed the first coarse ionospheric map is computed, and then the UPC predicted GIM is used in order to get the residuals where the TOMION voxels have been computed, see Figure 3.

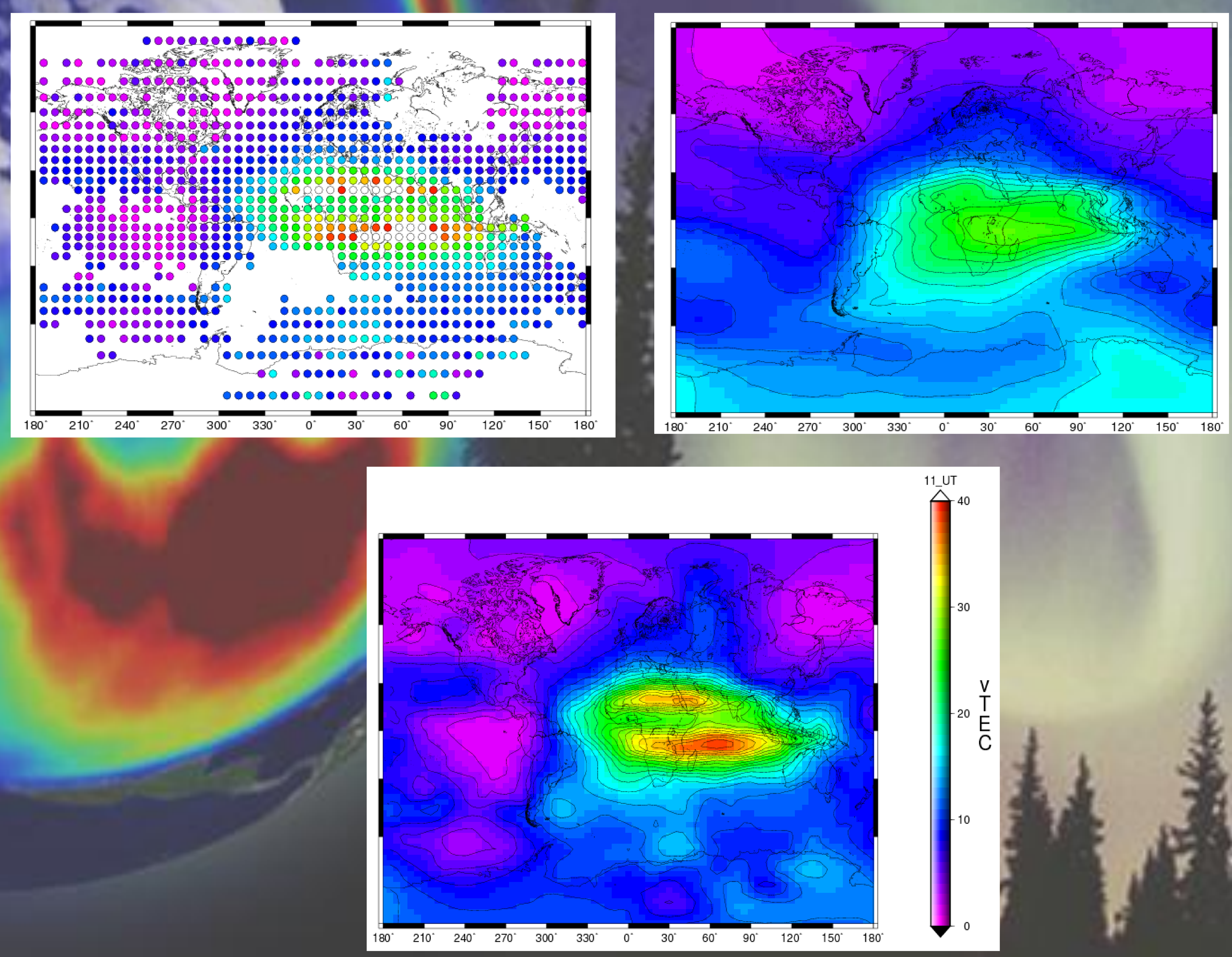

Figure 3: TEC maps for 11 UT of the doy 34 of year 2010. (Left-top panel) Real time integrated voxel determination, (Right-top panel) UPC prediction and (Bottom panel) Kriging based global TEC maps.

Afterwards, the kriging technique will be used in order to derive the final GIM at 5°x2.5° in longitude and latitude by means of using the above mentioned residuals, see Figure 3.

2.2.1 Real Time Ionosphere preliminary assessment

In the first runs of the prototype computations, large continuous assessments are difficult to perform. However, a preliminary assessment along with the UPC rapid and predicted ionospheres are done in order to cope with the global performance of this new ionospheric product. As it has been done in previous works, the assessment will be done with the altimeter ionospheric JASON VTEC data. The first results indicate that the Real Time UPC ionosphere can achieve comparable performance as the other ionospheric products, but at this moment the stability and real time coverage are important issues to solve. So the global performance is affected. In the Figure 4 there is an example on how the Real Time map behaves better than the base (predicted) map.

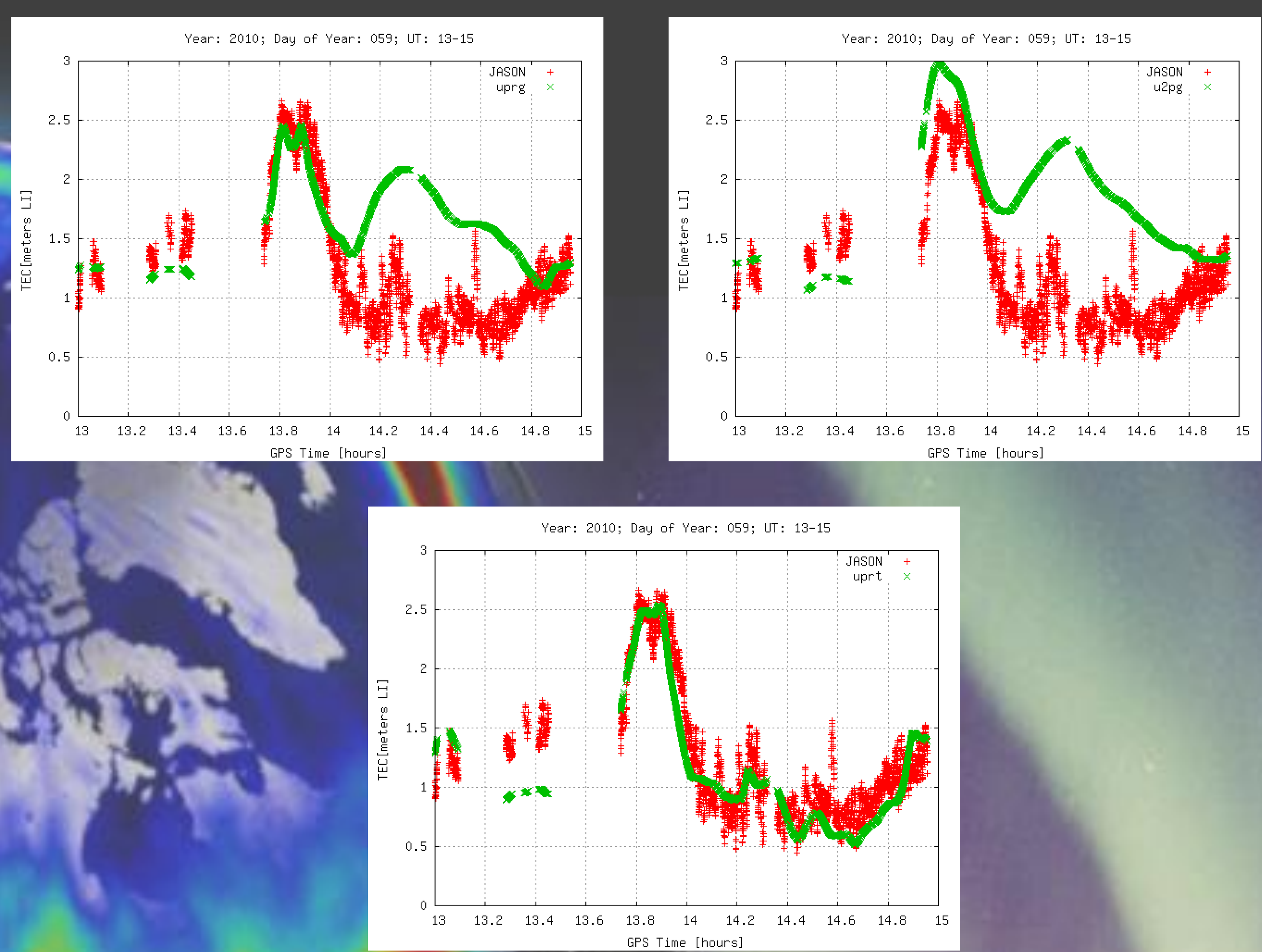

Figure 4: JASON comparison. (Left-top panel) UPC rapid ionosphere, (Right-top panel) UPC predicted ionosphere and (Bottom panel) Kriging based Real Time ionosphere for the doy 59 centered at 14 hours.

The day in Figure 4 represents the TOMION performance of a continuous full day of actual real-time data where the overall error for the different maps are 46.5%, 34.1%, 28.9% and 32.2% for the Predicted (u2pg), Rapid (uprg), Final (upcg) and Real Time (uprt) respectively.

3. CONCLUSIONS

The TOMION real time capabilities have been presented. It is clear that the performance is close related with the stability of the real time algorithms but as well with the coverage of the raw real time data. In this sense, the large data gaps over the Pacific ocean and Asia compromise the overall performance since the estimation and interpolation of the TEC data is highly affected. However, in the regions where there is enough coverage the new Real Time maps present good performance. Moreover, the interpolation of the map with respect to the predicted UPC maps shows good behavior since it can give quite different, independent and better values from the base map when this last one is far from the real time estimation. Therefore, improvements on the predicted maps would impact positively in the final estimation of the Real Time TOMION ionospheric maps.

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Courtesy: http://stereo.gsfc.nasa.gov