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Real Time Global Ionospheric Maps: a low latency alternative to traditional GIMs

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ABSTRACT

Since the late nineties different entities have been generating and distributing Global Ionospheric Maps (GIMs). In this time, multiple new application have arisen from the determination of electron content distribution and time evolution at global scale: from the more direct correction used by GNSS users up to measurement of solar EUV flux rate during solar flares, at global scale ([5], [10]). Moreover specific applications to precise real-time positioning and potential detection of tsunamis at regional and continental scales ([7], [3]) are also active fields of work. However, the latency to access the GNSS data and the computational time was too high to make real time GIMs. Nowadays thanks to the internet, which allows having real time access to permanent GNSS receiver's raw data, the maturity of the ionospheric modelling techniques and the computational power of modern computers we are able to compute different real-time ionospheric products. Indeed, they can be computed at regional, continental and global scales [9], in particular generating real time GIMs.

In this paper, we make a review of four real time GIMs generated by the following entities:
- Centre national d'études spatiales (CNES): Based on the estimation of spherical harmonics, as defined by the RTCM special committee ([11] stage 2 SSR messages).

- Technische Universität München (TUM): Based on the development of a near real-time data adaptive filtering framework for global modelling of the vertical total electron content (VTEC, [13]).
- Universitat Politècnica de Catalunya (UPC): Based on a Tomographic Model of the Ionosphere electron content (TOMION) which is and assimilative model of global GPS data ([4], [8]).
- Chinese Academy of Sciences (CAS): The global ionospheric TEC is modeled based on the spherical harmonic function by combing the real-time multi-GNSS raw observations and the 1-day predicted GIM and DCB with a compromise and sophisticated weight ([12]).

We compared the performance of the previous four RT-GIMs between them and two reference GIMs, IGSG and UQRG ([6]). Two different well-established techniques for traditional GIMs is used for the assessment: the standard deviation to altimeter data (direct Vertical Total Electron Content, VTEC, measurements) and the ΔSTEC (slant TEC referred to the highest elevations one) observed with GNSS receivers, which were not involved in the generation of the RT-GIMs.

The altimeter observations provide direct and independent VTEC measurements. There is a small offset of a few TECu between the altimeter data and RT-GIMs [1] due to the altitude of the satellite not including the entire ionosphere, and to any potential altimeter calibration bias. Although, this has no impact to the TEC variation, with differences between models much larger, and therefore we are using the standard deviation as a quality factor.

The ΔSTEC consists in, for a fixed receiver and for all the satellites in view from the considered receiver, calculating the difference of the slant TEC for every observation with the observation at the maximum elevation of the satellite [2]. Using an independent receiver ensures validating the real error of the RT-GIMs and not the model fitting error.

This paper will present the results of the comparison of the different models, allowing assessing the current readiness level of the real time GIMs and the performance of them. It will also show the different current techniques. One important point reviewed will be how the obtained information, e.g. the real time GIMs, are made available to the end users, including format differences (such as IONEX and RTCM) and latency. Finally, we will show possible future applications of this technology by the different institutes.

Key words: Ionosphere, GNSS, RT-GIM, Comparisons, Model Validation, Vertical TEC

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